G.R. III
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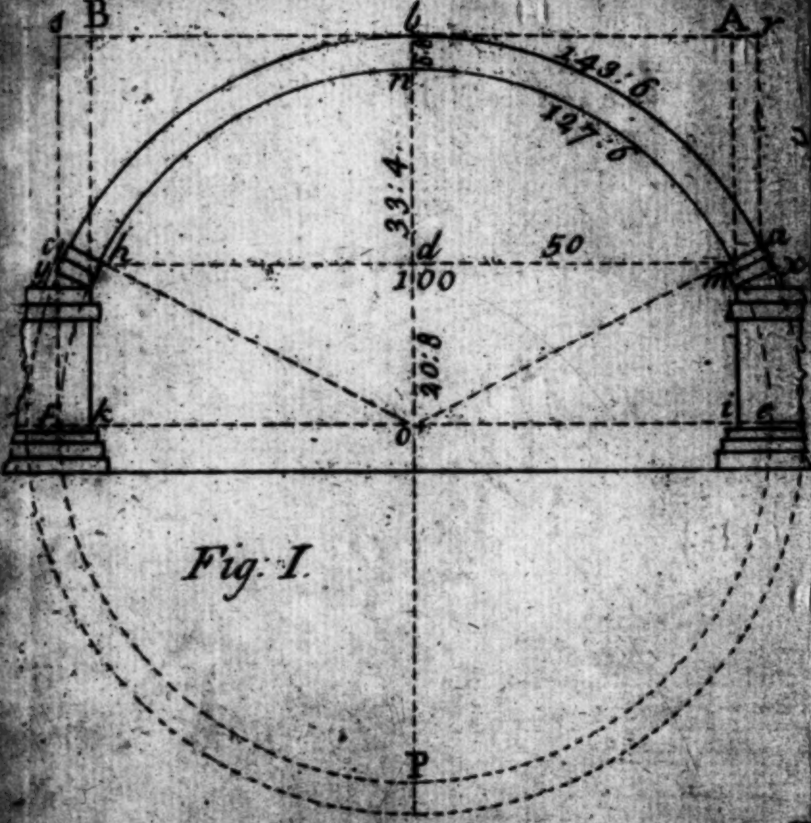
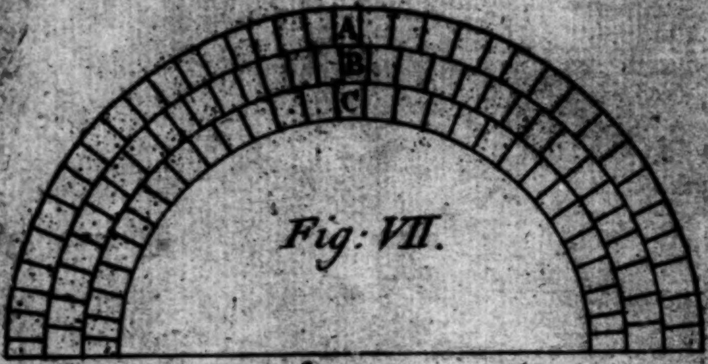


Fig: I.



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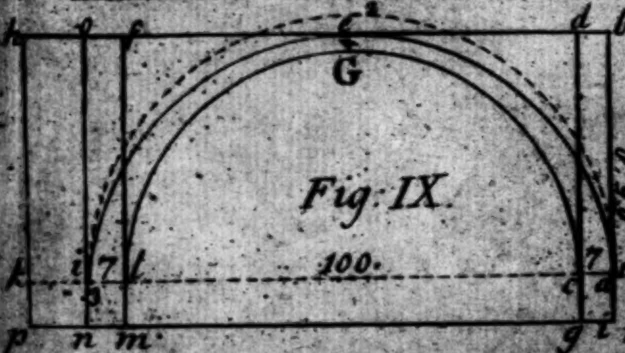

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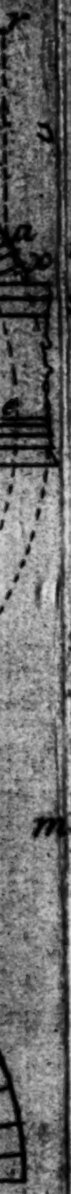

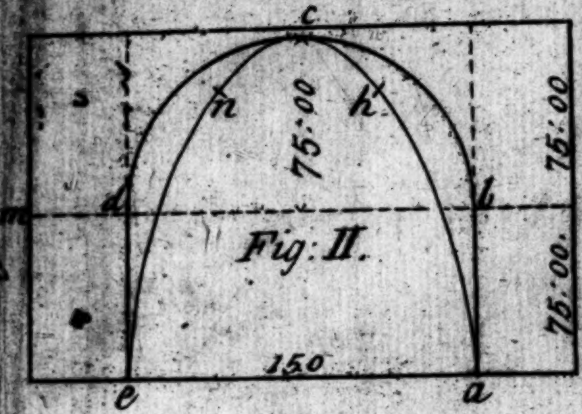

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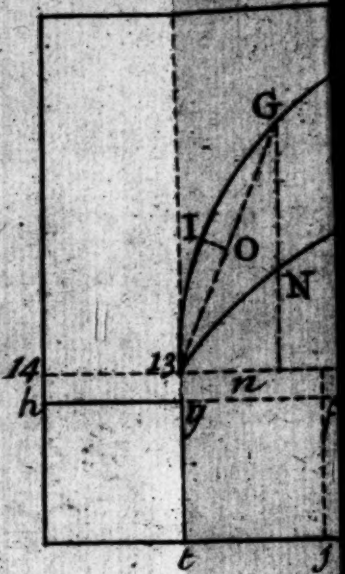

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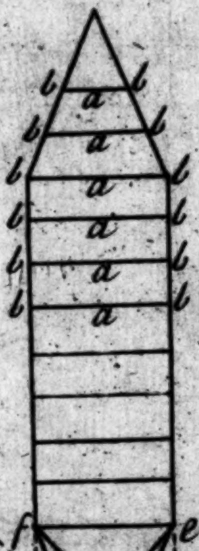

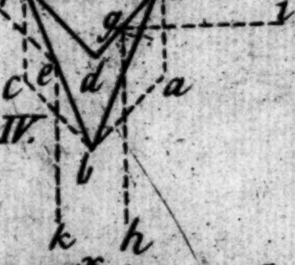

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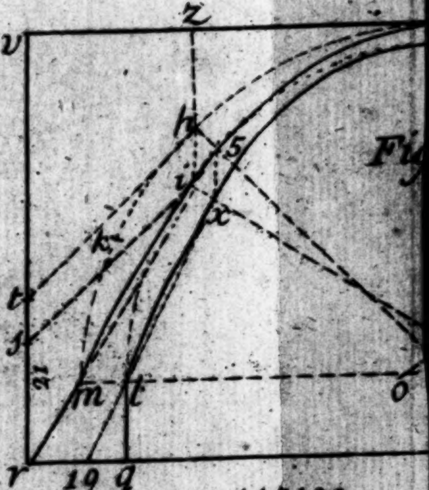

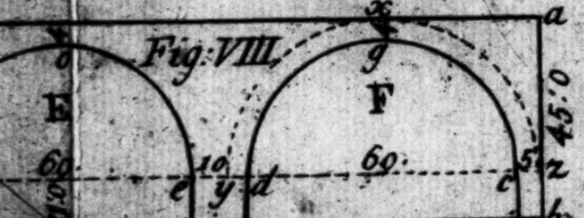

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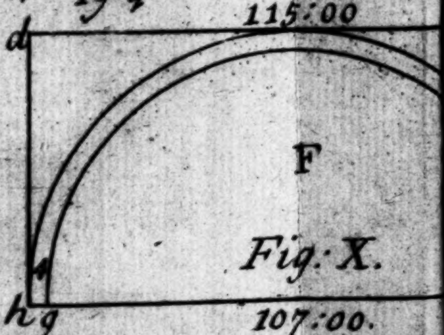

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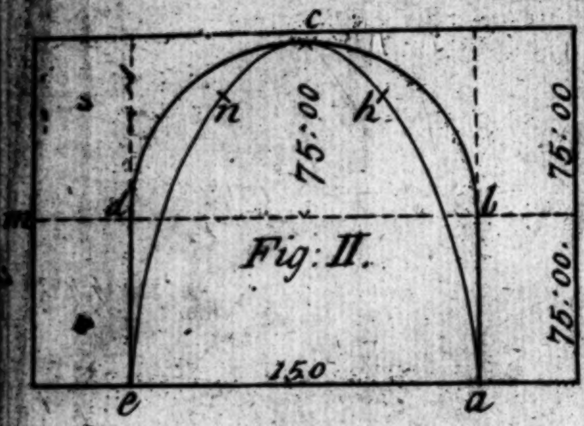

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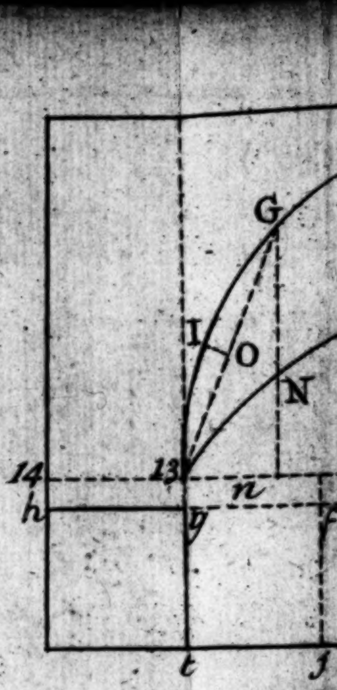

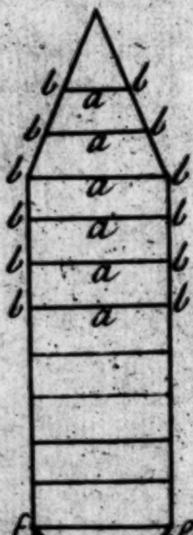

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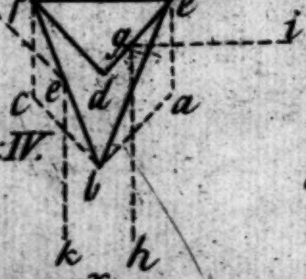

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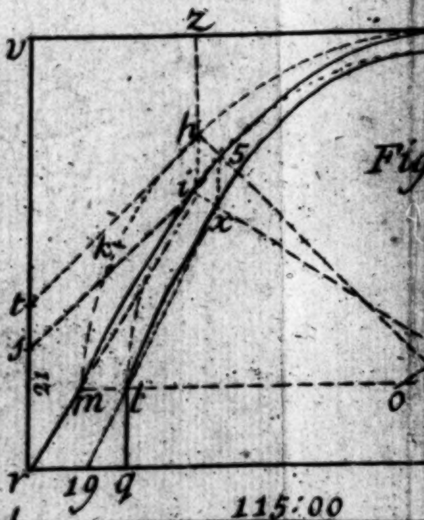

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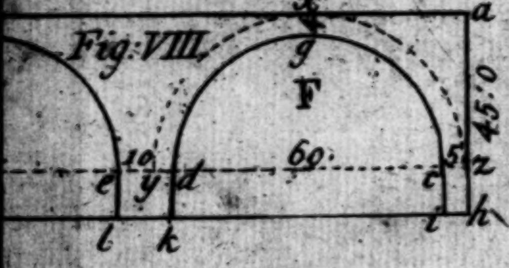

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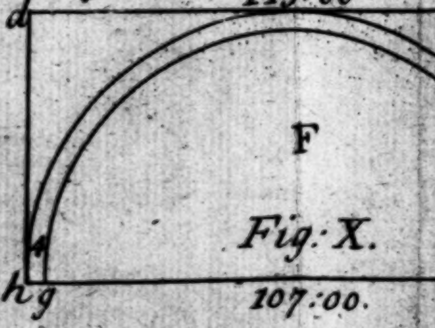

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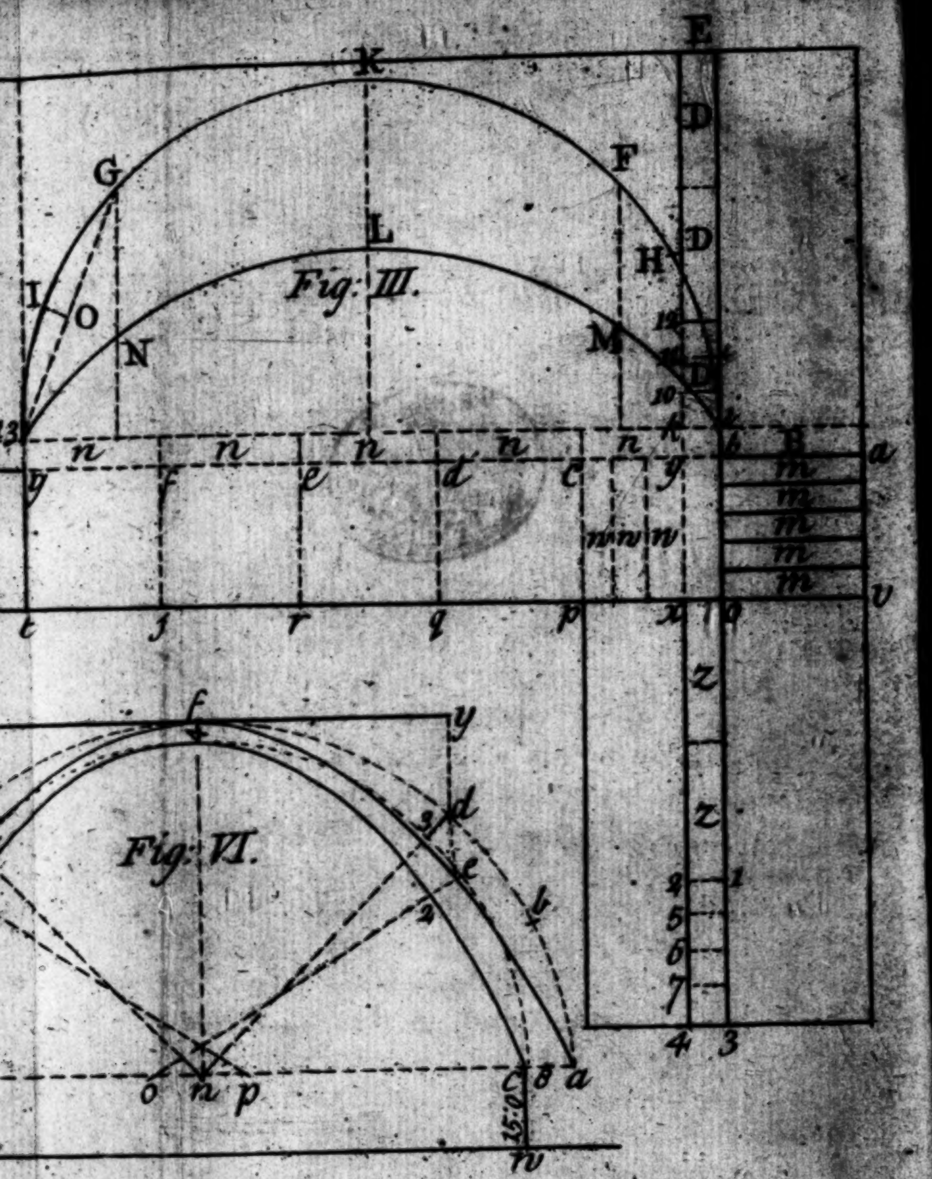
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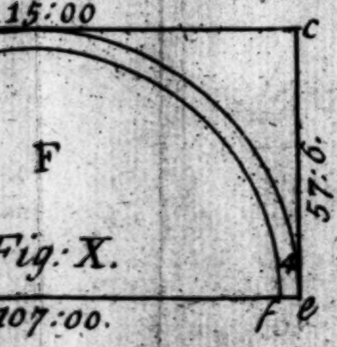
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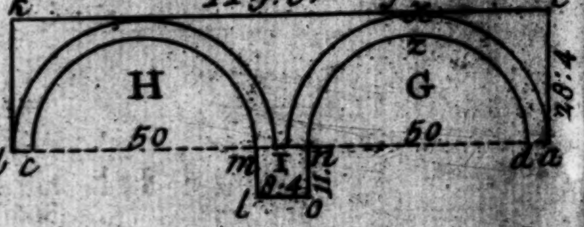
Fig: XI.

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A
REPLY
TO
Mr. *John James*'s Review
Of the ſeveral
Pamphlets and Schemes,
That have been offer'd

To the Publick, for the Building of a Bridge at *Weſtminſter*; wherein his many Abſurdities are detected, and the Manner of Meaſuring and Calculating the Quantity and Weight of Materials in all Kinds of Arches, explain'd.

By which 'tis evident,

That Mr. *James* is abſolutely a Stranger to ſo much Geometry as is needful to come at the Meaſures of the Quantities of Materials to be imploy'd in ſuch a Work, *&c.* And that a ſemicircular Stone Arch of 120 Feet in Diameter, has not ſo great a Preſſure on its Baſe, as many Publick Buildings in this Kingdom have on theirs. Alſo,

The Nature of the Tides, and Fall of Water at *London* Bridge, fully Explained. The Whole Exemplify'd by Geometrical Diagrams, and New Deſigns; demonſtrating the Nature and Eaſy Performance of ſo great a Work.

By *B. LANGLEY.*

LONDON:
Printed for the Author; and Sold by J. Millan,
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Where may be had, Price 1 *s.*

The FIRST PART of

A Deſign for the Bridge at New Palace Yard, *Weſtminſter*, compoſed of *Nine Arches*, independent of each other, whoſe Nature is ſuch, that the greateſt Weight poſſibly to be impreſſed cannot break them down. Admitting 880 Feet Water-Way for the Flux and Reflux of the Tides. Wherein is demonſtrated,

I. The ſeveral Manners that the Tides will be affected by this Building.

II. The greateſt Fall of the Water truly calculated; with Remarks on an erroneous Calculation of 4 *Inches and* 7 10*ths*, lately publiſhed.

III. Methods for laying the Foundations of the Piers in the moſt ſubſtantial and expeditious Manner, and to erect them with the ſame Eaſe as on dry Land, without Obſtruction to the Navigation.

IV. A near Calculation of the cubical Feet contained in the whole Fabrick; the Expence if built entirely with Stone, or with Stone and Brick.

V. The great Uſe and Advantage of horizontal Cylinders, for adjuſting an equal Preſſure on the Sides of each Arch.

A Work entirely new, by which an Expence of 24,174 *l.* is ſaved, and the Building made ſtronger alſo. With Obſervations on the ſeveral Designs publiſhed to this Time, proving the Abutments of their Arches to be infirm, and the Poſſibility of their Falling, by Means of which the Whole will be in Danger. By B. *Langley*.

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To the Right HONOURABLE

The LORDS,

And Others,

The Honourable Gentlemen, *appointed* Commiſſioners, *for building a Bridge croſs the River* Thames, *from the New Palace Yard in the City of* Weſtminſter, *to the oppoſite Shore in the County of* Surrey.

My LORDS *and* GENTLEMEN,

ALtho' at this Juncture, few Artiſts have any Hopes of ever ſeeing Men of Merit, precede thoſe of Impoſture and Intereſt; which diſcourages many, from applying their Thoughts for the Service of the Publick; yet, my LORDS and GENTLEMEN, in this Great and Laudable Undertaking, I am confident, that the Offers of every one, made unto *You*, will be impartially Conſider'd and Encourag'd, as their Abilities and Merits deſerve; without Regard to the private Intereſt of unqualify'd Perſons, who are the *Bane* of all Artiſts as well as of all Buildings raiſed by them; of which, the *Cuſtom-Houſe*, *Admiralty-Office*, and many other Buildings, in, and about this City, are Witneſſes to Futurity.

It is on this Motive, and with Regard to the Good of my Country, that I have imploy'd, with great Aſſiduity, many Hours, in the Contemplation hereof; and if it ſhould happen, that I have given, or may hereafter give, any Hints, or Inſtructions, that will be any wiſe ſerviceable in this Great Performance, I ſhall think my Time very Happily ſpent.

As Mr. *John James* of *Greenwich* (in his Short Review of the ſeveral Pamphlets and Schemes, that have been offer'd to the Publick, relating to this Work) has, miſtakenly printed and publiſh'd, a Series of Abſurdities, which, if not detected, might introduce a Kind of Thinking, founded on falſe Principles; I am therefore indiſpenſably oblig'd to expoſe them; in Regard to my own Reputation, and Juſtice to the Memories of the deceaſed Mr. *Hawksmore* and Mr. *John Price*.

Much more may be ſaid on this Great Work, which I am ready to communicate in the moſt familiar Manner, by Plans and Models, when Your HONOURS, will be pleas'd to lay your Commands on me for that Purpoſe. *I am,*

My LORDS *and* GENTLEMEN,

Your moſt Obedient, and

moſt Humble Servant,

Batty Langley.

A
REPLY
TO
Mr. James's *ſhort Review of the ſeveral* Pamphlets *and* Schemes *that have been offer'd to the Publick, in Relation to the building of a* Bridge *at* Weſtminſter, *&c.*

AS *the Conſtruction of Bridges is* undoubtedly *a Part of Architecture, which require a good Judgment and ſound Reaſoning*, both in the Principles and Practice of that Art; therefore, whoever is proved to be unacquainted therewith, cannot be a proper Perſon to be employ'd in ſuch Works.

And it is certain, that to build Bridges, (*p.*2.) *over wide and deep Rivers, where the Currents are ſtrong and impetuous, and, perhaps, the Bottom inſecure of itſelf; to build on will exerciſe the utmoſt Skill and Induſtry of the moſt knowing Perſon in the Buſineſs of*

Building, to conduct them with Reputation and Safety: But ſurely, this is not brought as an Inference (that becauſe the Breadth of the River *Thames* againſt *New Palace-Yard Weſtminſter*, is upwards of a thouſand Feet,) to conclude 'tis a deep River, that its Current is ſtrong and impetuous, and its Bottom inſecure to build on.

At the Times of low Water, the Depth (for the greateſt Part of the River's Breadth) is about 5 Feet, and in the deepeſt Part, which is on the *Lambeth* Side, for about 100 Feet Extent, not fully 10 Feet; which cannot be deemed deep, even at a common Spring Tide, whoſe perpendicular Altitude is generally about 10, and ſometimes 11 Feet more: Nor can the greateſt Velocity of the Current be called impetuous, as not being rapid or violent. And with Regard to the Security, or Inſecurity of the Bottom, I believe Mr. *James* cannot aſſert any Part of it to be either; but be that as it will, there are many Ways and Means to be uſed, that will make the Foundation entirely Firm and Secure, without any Kind of Difficulty, notwithſtanding there is a conſtant Flux and Reflux of the Tides, which Mr. *James* apprehends will make *the Difficulty of the Undertaking not a little augmented* (p. 4.). Had Mr. *James* ſaid 'twould have augmented the Expence, he had ſpoke like a *very knowing Perſou in the Buſineſs of Building.* But to ſay, it will augment the Difficulty, is abſurd; for if the *Batterdeaux*'s or *Cofferdam*'s are made ſecure at their Baſes, to keep off the Water, for 5 Feet in Depth, the natural Depth of the River juſt before the Tide flows, there's no Difficulty to encreaſe their Thickneſſes, and raiſe them high enough, to keep off, as many, twice as many, &c. more Feet in Depth; more of which, I am ready to prove, before the Honourable Commiſſioners, when they are pleaſed to lay their Commands on me for that Purpoſe.

As Mr. *James* cannot approve of any one Thing propoſed for this Work by Mr. *Price*, Mr. *Hawkſmore*, and his Humble Servant; and, as he ſays, it will exerciſe the utmoſt Skill and Induſtry of the moſt knowing Perſon in the Buſineſs of Building, (*p.* 4.) by which he undoubtedly would have himſelf to be underſtood: It will therefore be neceſſary, as I proceed, juſt to cite ſome one or two of the Buildings conducted by himſelf; by which every one may judge, how much he has regarded *Reputation* and *Safety*; and how great his Abilities are, in the Buſineſs of Building.

It is very remarkable that *Mons Gautier*, who is the firſt Perſon Mr. *James* takes Notice of, (*p.* 4.) ſhould eſcape his Cenſure, and particularly when ſo replete with Envy and Malice to the greateſt Degree, and ſo much overwhelm'd in Self-conceit, as to believe himſelf the only knowing Perſon in the Buſineſs of Building, (*p.* 4.) to have the only Underſtanding, how to weigh and conſider the Impediments and Hazards that inevitably attend Works of this Nature (*p.* 5.); that he's not one of thoſe *Perſons among us, who think themſelves qualified to give Inſtructions upon this Head*; and not capable to *contrive*, or *conduct a private Building*; or one who can draw the Plan and Upright of a Bridge, and at all Events, puſh forward to have his Scheme preferr'd, be it ever ſo impracticable. Or, who is not *Maſter of ſo much Geometry or Arithmetick, as is needful to come at the Meaſures, or to caſt up the Quantities of the Materials to be made Uſe of.* No; he believes himſelf to be no ſuch Perſon; but *at the ſame Time, might be conſcious,* *were* he *capable of Reflection*, that many have laugh'd at ſome of his Performances, of which, the Roof that he made to *Well-Hall*, lately ſtanding near *Eltham* in *Kent*, was one, which 'tis ſaid would have fell down before tiled in, had it not been ſhored up from the Ground to prevent it. Nor could any Man, with Safety and Reputation, depend on him for the contriving or conducting of his own Work, I mean, that of a Carpenter, when he worked at that Trade, until Mr. *Abraham Curtis*, an excellent Workman, acted for him, and taught him that Buſineſs; and who, for ſo doing, I am informed, he treated with the utmoſt Ingratitude. Now ſeeing that many ſuch riſe in the World *more by Fortune than Merit*, and take the Liberty to make their Offers, *poor ones as they are*, and with very great Aſſurance puſh to have them preferred; pray, Why is not every Man of Modeſty and Merit, to be admitted, at leaſt, the ſame Liberty? May not from one or more of ſuch, ſomething be produced and offered to the Advantage of this Work; that cannot be ſpontaneouſly produced from Mr. *James*'s Brain, and which cannot be cultivated in its heavy, ſtubborn Soil?

His Reflection on thoſe Men (who make no more Difficulty to propoſe Arches of 100 or 120 Feet in Extent (*p.* 6) than others would of 40 or 50) will retort directly on himſelf; for, inſtead of his ſaying that their Ideas are generally ſo very ſuperficial, that they *ſeem* to have little or no Notion of the Effects of Weight and Solidity, his Ideas will herein be *proved* to be actually ſuch, and that he really is not Maſter of ſo much Geometry and Arithmetick as to come at the Meaſures of the Quantities of Materials to be made

Uſe of in this Undertaking, altho' he has had the *Aſſurance* (*p.* 57.) to ſay, *The Calculations he has hitherto made, do not only concern the Cubical Quantities of Stone requiſite for the Work, but the Workmanſhip itſelf, and the Charge of raiſing it and ſetting it alſo.*

But leaving his envious Reflections to ſuch as will give Ear to them, I come now to examine his Review.

His firſt Bounce is at Mr. *John Price*, lately deceaſed, which ſeems to be no more than that of a Pot-Gun; nor is his ſecond (which is at Mr. *Hawkſmore*) of much greater Report; but his third and laſt, is very much like that of a *Blunderbuſs*; as will frequently appear in the following Diſcourſe.

His Remarks on Mr. *Price* are as follows, *viz.* 1. That his Side Arches are 40, 55, 70, 85, and the middle Arch 100 Feet wide (*p.* 6.); that the Peers of his Bridge have their Thickneſs very well proportion'd to the Extent of their reſpective Arches; but their Altitudes 23 Feet, from the Bed of the River, before the Arches come on, not ſo; being, as he imagines, ſomething too highly advanced; but how much, and what Conſequences ſuch extraordinary Height might have been attended with, he has forgot to make any Mention of. But, however, he concludes, that *he cannot think it adviſable to ſet an Arch that riſes no more than $\frac{1}{3}$ of its Diameter of ſo great Weight and Thruſt as the middle one, eſpecially upon Legs ſo advanced.* (*p.* 7.)

2. That *the Periphery of this Arch is much about 128 Feet, and in Proportion to its Extent, the Arch Stones ought to be 7 Feet, or at leaſt 6 Feet 8 Inches in Depth*: I ſhould be very glad to know, how

this Proportion is produced, and on what Principles it is ſounded. It would have been more like a *very knowing Perſon in the Buſineſs of Building*, had Mr. *James* demonſtrated it, by proving that a leſſer Thickneſs or Depth would not ſuſtain the Weight of ſuch an Arch; than to ſay, 'tis ſo, without Demonſtration. In the next Place he obſerves, that *the Breadth of the Bridge* aſſigned by Mr. *Price*, from out to out of the Parapet Walls is 40 Feet; and then ſays,

" *Now the multiplying* 128 *Feet, by* 6 *Feet* 8 *Inch-*
" *es; by* 40 *Feet, produces Cubical Feet* 34133 *Feet*
" 4 *Inches for the ſolid Content of the Arch, which*
" *admitting the Arch to be of* Portland *Stone, are*
" *of no leſs Weight than* 2133 *Tons, the Burthen of*
" *four or five large Ships.*

I muſt here take the Liberty to obſerve, That Mr. *James*, in this Calculation, proves himſelf to be one of thoſe very Perſons, whom he ſays (*p.* 6.) are not *Maſters of ſo much Geometry and Arithmetick, as is needful to come at the Meaſures, or to caſt up the Quantities of the Materials to be made Uſe of.* For 853 Feet 4 Inches, produced by multiplying the Curvature or Periphery of the under Part of the Arch (as *m n b*, *Fig.* I.) 128 Feet, into 6 Feet 8 Inches its Depth, is not the ſuperficial Content of the Figure *a b c m n b*, which is the Face of the Arch, and conſequently, that Product being multiplied into 40 the Breadth of the Bridge which produce 34133 Feet 4 Inches, cannot be the cubical Quantity of the Arch, as he has aſſerted it to be.

Had Mr. *James* been Maſter of ſo much Geometry, as is neceſſary to meaſure the Superficies of the Face of the Arch *a b c m n b*, he would have known, that deducting the Sector *m n b o*, from the

Sector *abco*, the Remains *abcmnb* would have been the ſuperficial Content thereof.

As the Manner of meaſuring the Superficies of this Arch, will be a Guide to Mr. *James* in future Computations; and, perhaps, ſome Entertainment to the Curious, I will therefore ſhew,

How to meaſure the Superficies *of the Face of an Arch.*

Let *abc* be the upper Curve, and *mnb* the lower Curve. Let *mb* the Extent, or Chord Line of the leſſer Curve be equal to 100 Feet; the Height *dn*, equal to 33 Feet $\frac{1}{3}$ (which is $\frac{1}{3}$ of the Extent of the leſſer Curve); and *bn* equal to 6 Feet 8 Inches, the pretended proportional Depth.

Firſt, Find the Diameter *n*P of the leſſer Curve *mnb*, thus, *arithmetically*.

RULE.

1*ſt*, Square its half Chord *md* (which is no more than to multiply 50 into 50). Divide its Product (2500) by *dn* its Sine or Height ($33\frac{1}{3}$) and add the Quotient (75) to *nd* the Sine, and the Sum 108 $\frac{1}{3}$ is equal to *n*P the Diameter required.

Secondly, Find the Lengths of the two Curves *mnb*, and *abc*, by theſe

RULES.

1*ſt*, Draw *ef* equal to 108 Feet $\frac{1}{3}$, the Diameter found; on *o* its Center with the Radius *eo*, deſcribe the Semicircle *enf*; alſo on *o*, erect the Perpendicular *on*: Make *io*, and *ok*, each equal to 50 Feet, and draw *im*, and *kb*, parallel to *on* cutting the Semicircle in the Points *m* and *b*, and draw the Lines *mo*, and *bo*.

2dly, As 7 is to 22, ſo is 108 $\frac{1}{3}$, the Diameter of the Circle *enf*P, to 340 $\frac{3}{7}$ Feet, its whole Circumference.

3dly, As 360, the Degrees in the whole Circumference,
Is to 340 $\frac{3}{7}$, the Number of Feet contained therein,
So is (135 Degrees) the Quantity of the Angle *mob* (which are equal to the Degrees contain'd in the Arch *mnb*) to (127 Feet and $\frac{1}{2}$, and a little more) the Length of the leſſer Curve, which Mr. *James* ſays is about 128 Feet.

To find the Length of the upper Curve abc; to 108 Feet 4 Inches the Diameter of the leſſer Curve, add twice 6 Feet 8 Inches, for the Thickneſs of the Arch on each Side; the Sum is 121 Feet 8 Inches; then ſay,

1ſt, As 7 is to 22, ſo is 121 Feet 8 Inches, to 382 Feet $\frac{2}{7}$, the Circumference of the outer Circle.

2dly, As 360 Degrees, is to 382 Feet $\frac{2}{7}$, ſo is 135, the Degrees in the Arch *abc*, to 143 Feet 6 Inches, the Length of the upper Curve; which exceeds the lower Curve by 16 Feet, of which Mr. *James* takes no Notice, but proceeds as if both were equal.

The Lengths of theſe Curves and their Radius's being thus found, the Areas of the Sectors *abco*, and *mnbo*, may be found ſufficiently near, as following, *viz.*

Multiply half the Curve Line by the Radius, and the Product is (nearly) the Area required.

So half *abc*, 71 Feet 9 Inches, multiplied into the Radius *oq*, 60 Feet 10 Inches, the Product is 4364 Feet 9 Inches and a half; and the half *mnb*, 63 Feet 9 Inches, multiply'd into 54 Feet 2 Inches, the Product is 3453 Feet 1 Inch and $\frac{1}{2}$.

If from 4364 Feet 9 Inches and $\frac{1}{2}$, the Area of the Sector *abco*, we ſubtract 3453 Feet 1 Inch and $\frac{1}{2}$, the Area of the Sector *mnbo*, the Remains is 911 Feet 8 Inches, which is the ſuperficial Content of *abcmnb* the Face of the Arch as requir'd. Now 911 Feet 8 Inches multiply'd into 40 the Breadth of the Bridge, produces cubical Feet 36466, 8 Inches.

If from 36466 Feet 8 Inches, which is the true Quantity of Stone in the Arch, be ſubtracted 34133 Feet 4 Inches, the pretended Quantity by Mr. *James*, the Difference is 2333 cubical Feet; which divided by 16, the Feet cubical in a Tun of Stone, the Quotient is 145$\frac{13}{16}$, the Number of Tuns miſtaken by Mr. *James* in this Particular.

Now ſuppoſing that ſuch an Arch as this was really built by a Maſon, and thus meaſur'd by Mr. *James*, it is evident, that by his Stupidity, the Maſon would be wronged of 2333 cubical Feet of Stone, which cannot be worth leſs than 3 *s. per* Foot, including working and ſetting, which amounts to 344 *l.* 19 *s.*

The next Thing that comes under Mr. *James*'s Conſideration, is, the Weight of the Spandrels on the Sides of the Arch, which he falſly aſſerts (*p.* 7.) *will be about* 2000 *Tuns more*, the Abſurdity of which appears very plainly from the following, *viz.*

1. Thro' the Point *b* draw the right Line *rs* parallel to *mb*; and from the Points *a* and *c* draw the right Lines *ar*, and *cs* parallel to *bd*. Then will *xy*, the Length of the Parallelogram *xrsy*, be equal to 112 Feet 4 Inches, and Height, *xr*, to 33 Feet 4 Inches, which being multiply'd into

each other, produce an Area of 4044 Feet 4 Inches. *2dly*, If 50, the half of *mb*, be multiply'd by *do*, 20 Feet 8 Inches, its Product 1033 Feet 4 Inches is the Area of the Triangle *mbo*. *3dly*, From 3453 Feet 1 Inch and $\frac{1}{2}$, the Area of the Sector *mnbo*, ſubtract 1033 Feet 4 Inches, the Triangle *mbo*, the Remains, 2419 Feet 9 Inches and $\frac{1}{2}$, is the Area of the Segment *mnb*; to which add 911 Feet 8 Inches, the Area of the Face of the Arch *abcmnb*, the Total is 3331 Feet 5 Inches and $\frac{1}{2}$. *4thly*, If from 4044 Feet 4 Inches, the Area of the Parallelogram *rsxy*, we ſubtract 3331 Feet 5 Inches and $\frac{1}{2}$, the Remains is 712 Feet 10 Inches and $\frac{1}{2}$, which is the Area of the Face of the two Spandrels.

Now 712 Feet 10 Inches and $\frac{1}{2}$ multiply'd into 40 Feet the Breadth of the Bridge, produces cubical Feet 28,515; which divided by 16, the cubical Feet in one Tun of Stone, the Quotient is 1782 Tons 3 Feet, which is 217 Tons 13 Feet leſs than 2000 Tons the Quantity aſſerted by Mr. *James*, and which at 3*s*. *per* Foot, for Stone, Work, Setting, *&c.* amounts *but* to 522*l*. 15*s*. to which I add his preceding Miſtake of 344*l*. 19*s*. and the Total Miſtake in this ſingle Article, is *no more* than 867*l*. 14*s*.

Mr. *James* ſays (*p*. 8.) *It may be queſtioned, whether any Stone now in Uſe among us, will, according to the common Manner of working, bear the Preſſure of its own conſtituent Parts in ſuch extenſive Arches, without ſuffering by it.* As Mr. *James* ſeems to be unacquainted with the Manner of accounting for the Preſſure of Arches; I will, for his further Improvement *in the Buſineſs of Building*, give him ſome Hints, which when underſtood, will teach him how to account for (and not gueſs at) ſuch Works for the future.

1*ſt*, To 911 Feet, the Area of the Face of the Arch, add 712 Feet, the Area of both Spandrels, the Sum is equal to 1623 ſuperficial Feet; and if we conſider the Whole at 1 Foot in Thickneſs, then they are to be conſider'd as ſo many cubical Feet.

The Baſes on which they are ſuſtain'd, are *x m*, and *b y*, each being nearly 6 Feet 2 Inches by 1 Foot, and Area 6 Feet $\frac{1}{6}$.

The half of 1623 being 811 $\frac{1}{2}$, is the Number of cubical Feet ſuſtain'd by each Baſe; and therefore if 811 $\frac{1}{2}$ Feet be divided by 6 Feet $\frac{1}{6}$, the Quotient is 131 $\frac{21}{37}$, which are the Number of cubical Feet of Stone, equal to 8 Tuns $\frac{3}{16}$, ſuſtain'd by every ſquare Foot of each Baſe. A very wonderful Weight indeed! and more eſpecially, if 'tis conſider'd, that the eight Legs, which ſuſtain the great Cylinder on which the Dome of St. *Paul's* is erected, carry more than three Times that Weight, and yet no Complaints are made by the very loweſt Stones, which bear the Weight of the Whole. If this be conſider'd, and that we can now have as good Stone as is in the Foundation of St. *Paul's*, is it not monſtrouſly ſhocking, that Mr. *James* ſhall thus make Mountains of Mole-Hills, and inſinuate Difficulties into the Minds of People where in Fact there's not any.

And as in the following Diſcourſe I ſhall prove that a Thickneſs of 4 Feet is fully ſufficient on the Head of a ſemicircular Arch whoſe Extent is 120 Feet; it is therefore to be here noted, that allowing 7 Feet in Extent on each Side of ſuch an Arch, for the Extenſion of its Baſe, every ſquare Foot in the Area of ſuch Baſe, will ſuſtain but little more than the Weight of 208 cubical Feet, which is nearly equal to the Weight that is on each ſquare Foot of the Baſe, under the Shaft of the monumental Column on *Fiſh-ſtreet-Hill, London.*

Mr. *James's* next Sneer on Mr. *Price is*, (*p.* 8.) That he's *very much in the right, where he conceives it proper, to have truſs'd Centers under every Arch, from Pier to Pier to turn the Arches upon; and that there is a good deal of Skill requir'd to make a Center of this Kind, which muſt bear, perhaps, two or three thouſand Tuns, before the Arch is finiſhed ſo far as to relieve it.* Had Mr. *James* ſpoke here in the Affirmative, and told us the poſitive Weight, or nearly thereto, as the Arches muſt ſuſtain, he had expreſs'd himſelf like a *very knowing Perſon in the Buſineſs of Building*; but ſaying *two, or three Thouſand Tuns*, is more like one (*p.* 6.) *whoſe Ideas are ſo very ſuperficial, that they ſeem to have little or no Notion of Weight and Solidity.*

If from the Points *m* and *h*, in *Fig.* I. the right Lines *m*A, *h*B are drawn parallel to *bd*, and the Areas of the Parallelograms B*sbc* and *r*A*am*, which together are equal to 411 Feet, be ſubtracted from 1623, the Area of the Arch and both Spandrels taken together, the Remains is 1212 Feet; which multiply'd by 40 the Breadth, and its Product 48480 divided by 16, the Quotient is 3030, which are the Number of Tuns Weight, contained in the whole Arch, between the Uprights of its Peers. But as the Center will be relieved, ſo ſoon as the uppermoſt *Vouſſoirs* are ſett, which is generally done when the Spandrels are brought up to about half their Height, then the remaining Part of the Weight will be ſuſtain'd by the Arch, and the Center may be removed away when required.

The gradual lowering of the Centers, which Mr. *James* makes ſlight of, and recommends to be left to the Diſcretion of the Workmen who may be employ'd to make them; I humbly conceive to be a Matter not ſo eaſily to be paſſed over; for if very great Care be not taken therein, the Arches may be greatly damaged; the Lives of many Workmen endanger'd; and, as Mr. *James* (in many Caſes that he ſeems not to underſtand) ſays, *Perhaps* the Arches themſelves may be thrown down; of which many melancholly Inſtances have been, with Arches of much leſs Magnitude.

The other Remarks of Mr. *James*, on Mr. *Price*'s Deſign, and Diſcourſe on Bridges abroad, conſiſting wholly of Self Praiſe, Conceit, and ill Nature; I ſhall therefore reject them, as being unworthy of my Notice; and proceed to his Remarks on the late Mr. *Hawkſmore*, to whom he's largely indebted for a great Part of the ſmall Share of Knowledge he's now Maſter of.

As the Methods uſed for building of *London* Bridge is unknown to us, and the various Opinions about it wholly Conjecture, I ſhall not take any Notice of Mr. *James*'s Thoughts thereon: But why he ſays (*p.* 15.) that *the Foundation muſt be the worſe, and not the better, for Planks to intervene between the Stone and the Timbers*, by which, I ſuppoſe, he means the Piles, I muſt own, I do not underſtand.

If the Legs of that Bridge ſtand on Piles, as 'tis very reaſonable to believe they do; and if on their Heads there be a double laying of ſtrong Plank ſpiked down, to make a level Bed, on which, perhaps, ſubſtantial Joiſts are cloſely laid at right Angles over each other to receive the firſt Courſe of Stones, I can't ſee why the Foundation can be the worſe. I could have wiſh'd that this had been ſo explain'd by Mr. *James, that one might, by reaſoning thereon, diſcover the Truth or Fallacy of his Aſſertion.*

Mr. *James*'s Remark on the Tide of Flood being retarded by the Piers of *London* Bridge, during the Time of its greateſt Velocity, to be an Advantage to Veſſels of Burthen, being thereby ſooner floated up to the Keys, is undoubtedly true; for by the Water's being ſo obſtructed, it riſes in the Beginning of the Flood to a much greater Height below the Bridge in the ſame Time, than it would do, was it not ſo obſtructed; but at the Time of High Water, when the Water is level on both Sides the Bridge, the Height is no more than it would be, was there not any Bridge in that Part of the River; for was it poſſible then to remove away the Bridge in an Inſtant of Time, the Height would remain as before; a very ſmall Abatement excepted, which would be required to fill up the Space that its Legs poſſeſs; and which would be ſo very inconſiderable, as not to be eaſily diſcover'd by the moſt curious Eye.

The Propoſition of Mr. *Hawkſmore* for making two large Arches at *London* Bridge for the better paſſing of Veſſels of Burthen thro' the ſame, is undoubtedly very good; for thereby the Fall would not only be ſomething abated (tho' not very much, as Mr. *James* ſays (*p.* 18.); becauſe there would be but little more than one ſixth Part of the preſent Obſtruction removed) but the Hazzard of Veſſels running upon the Stallings in thoſe Parts, would not be ſo great as at preſent it is, they being ſo very near together.

I cannot by any Means come into Mr. *James*'s Way of thinking, that theſe enlarged Arches would in the leaſt contribute to the raiſing of the

Tides of High Water higher at *Weſtminſter* than now happens. For tho' the Piers check the Flood during its Time of coming in, yet as the obſtructed Water is raiſed on the free Water, and doth paſs thro' the Bridge in the ſame Time, with an increas'd Velocity, it is juſt the ſame Thing as if it was to paſs thro' an Opening as large again with one half the Velocity. Indeed, as I before obſerved, was theſe Openings made, the Height of the Flood below the Bridge would not be increaſed ſo early in the Tide as it now is, but would nevertheleſs be always the ſame, tho' ſomething later in the Tide; and the Height of High Water the ſame alſo.

Mr. *James* ſays, Mr. *Hawkſmore*'s Bridge is deſign'd with good Judgment; a Wonder! but yet finds Fault with it, and ſays, (*p.* 19.) *That its Arches are of the largeſt*; *but has made them ſemicircular*, (not Catenarian as mine) *and taken their ſpringing at the low Water Mark, which adds very much to the Strength of the Legs that are to ſuſtain them.* I muſt own this to be above my Comprehenſion: For if it be granted that the Preſſure of the Weight be perpendicular upon the Piers; in what Manner can they be ſtrengthen'd thereby? Had Mr. *James* ſaid, that they are leſs liable to Injury by ſuch a downright Preſſure, than by the oblique Preſſure of the Scheme Arches, as propoſed by Mr. *Price*, I ſhould have underſtood him; but that they are made ſtronger thereby, requires Explanation.

The Ruſticity propoſed by Mr. *Hawkſmore*, and diſapprov'd by Mr. *James*, is no more than the common Spirit of Contradiction in the latter, who dar'd not thus preſume, in Mr. *Hawkſmore*'s Time, to have mention'd one Syllable thereof, and therefore I ſhall only add, that if the extraordinary Expence of working thoſe Ruſticks, in a Craggy, Rocky, Groteſque Manner, be not thought too great, nothing can be ſo Grand and Beautiful, if made large, nor ſo well adapted to the Situation and Purpoſe, notwithſtanding the Oblique Termination of every Courſe by the Deſcent of the Walls.

As great Wits always jump together (*p.* 21.) ſo Mr. *James* is of Mr. *Labelye*'s Opinion, *That there will be no ſenſible Fall at this Bridge, during the Flood*; *but that the Tide will not run ſenſibly higher between the two Bridges, ſo as to affect the Lands or Buildings on either Side, he cannot ſay.*

I muſt here beg Leave to obſerve, that if the Tide of Flood ſhould run ſenſibly higher between the two Bridges, it muſt make a ſenſible Fall at the new Bridge, where, on the upper Side, the Water muſt conſequenly be ſenſibly lower, otherwiſe that between the Bridges cannot be ſenſibly higher: And granting that ſuch ſhould be the Caſe; ſuch extraordinary Height can never happen, but during the great Velocity of the Tide before High Water, whilſt the Piers of the New Bridge retard its natural Courſe: For juſt upon High Water, when the Velocity is very ſlow, the Quantity obſtructed is very little; and the leſſer both the Velocity and Quantity obſtructed are, the more is the Fall diminiſhed; and even this at both Bridges in the ſame Proportion until the natural Force of the Tide be at an End, when the Fall is then wholly deſtroy'd, and the Water of the ſame Height on both Sides the Bridge, at which Time 'tis called High Water, and which continues but until the Tide in the lower Part of the River, by its own

Gravity, begins the Ebb, and returns back towards the Sea.

Hence 'tis plain, that neither the Lands, nor the Buildings between the two Bridges, at the Times of High Water, will be affected more than is common.

Mr. *James*'s next Obſervation is on Mr. *Labelye*'s Words (*p.* 22.) *viz. That were there no Retardation (as he calls it) to the Deſcent of the ebbing Waters, not only there would be no Fall, but the Tide of Ebb would not be ſo much longer than the Tide of Flood.* To this Mr. *James* anſwers, *is undeniably true*, and adds, that Mr. *Labelye* might as well have ſaid, *That were there no Bridge at all, there would be no Manner of Impediment given to the Current.*

Now I muſt beg Leave to obſerve, that the Reaſon of the Tide of Ebb being longer in running out, than the Tide of Flood running in, is occaſion'd by the Tide's Water meeting the Water of the River, during the Time of Flood, which make together a much greater Quantity than that produc'd by the Tide only; and therefore as the Quantity is ſo increaſed, and as the Current of the River is very gentle, it requires a much longer Time to empty itſelf than the Tide's Water only would do: For ſuppoſing that the River's Water be equal to $\frac{1}{7}$ of the Tide's Water, 'tis plain, that ſo long a Time as $\frac{1}{7}$ of the Whole is running off, ſo much the longer will the Whole be running away, more than if no ſuch River Water was added to the Tide.

If this be conſider'd, that which Mr. *James* ſays (*p.* 22.) *is undeniably true*, proves to be undeniably falſe, and which is very evident; for though the Tide of Ebb is obſtructed at *London* Bridge, and thereby the Fall is produc'd, yet I hope he will not ſay, that the Tide of Ebb is affected by *London* Bridge, ſo high up the River as to *Lambeth*, *Vaux-Hall*, *Chelſea*, &c. ; and if ſo, why then if *London Bridge* was to be taken away, the Times of the Ebb Tides would be in all thoſe Parts of the River the ſame as now. But to make this yet more plain, let it be conſider'd, that when 'tis Flood at *Graveſend* at half an Hour after 7, the ſame Tide doth not begin to flow at *London* Bridge till 10, at which Time it hath flowed 2 Hours 30 Minutes at *Graveſend*.

If to 2 Hours 30 Minutes, the Time of the Tide's flowing at *Graveſend* before it begins to flow at *London* Bridge, we add 5 Hours, the Time of flowing above the Bridge, the Sum is 7 Hours 30 Minutes ; out of which ſubtract 6 Hours, the Time of flowing at *Graveſend*, and the Remains is 1 Hour 30 Minutes, the Difference of Time between High Water at *Graveſend* and *London* Bridge ; and conſequently, when 'tis High Water at *London* Bridge, the Tide has ebbed 1 Hour 30 Minutes at *Graveſend*.

If 1 Hour 30 Min. be ſubtracted from 6 Hours 30 Minutes (the Time of Ebb at *Graveſend*) the Remains is 5 Hours, which are the Number of Hours, after 'tis High Water at *London* Bridge, before the next Flood is began at *Graveſend*.

Now ſince the Tide of Ebb at *London* Bridge is began at 7 Hours 30 Minutes after Flood at *Graveſend*, 'tis plain, that the coming on of the Flood from *Graveſend* up to *London* Bridge, is 2 Hours 30 Minutes, altho' the High Water at *London* Bridge is but 1 Hour 30 Minutes after that at *Graveſend* ; and which is no Wonder, if we conſider that the Velocity of the Tide in its very firſt

Advance againſt the natural Current of the River, is thereby in ſome Degree retarded, more than that which ſuccceds in greater Abundance, unto the Time of High Water.

As the Tide advances from *Graveſend* to *London*, and from thence to *Twickenham*, its Velocity is leſſen'd, not only by its Friction on the Bottom and Sides of the River, but by the ebbing Water of the River, which is conſtantly retarding its Approach as aforeſaid, and which is not only mixed with the Tide, but Part of it carry'd back again with it, whereby the Quantity of Water in the River, until High Water, is thereby much greater than it would be, were there no other Water but that proceeding from the Sea, to make the Tide, as hath been obſerved: And altho' the Diſtance from *Graveſend* to *London*, 20 Miles, is 3 Miles more than from *London* to *Twickenham*, yet the Velocity of the Tide from *Graveſend* to *London*, being greater than from *London* to *Twickenham*, the Time of High Water at *Twickenham* is about the ſame Space of Time after High Water at *London* Bridge, as High Water at *London* Bridge is after *Graveſend*, *viz.* 1 Hour 30 Minutes; and therefore when 'tis High Water at *Twickenham*, there is 3 Hours Ebb at *Graveſend*, and 1 Hour 30 Minutes at *London* Bridge. Now ſeeing that the Ebb at *London* Bridge is begun 1 Hour 30 Minutes before 'tis at *Twickenham*, 'tis no Wonder that the Water below Bridge is ebbed much ſooner than that above Bridge, which is flowing 1 Hour 30 Minutes longer: And if to this 1 Hour 30 Minutes be added 7 Hours, the Sum is equal to 8 Hours 30 Minutes, which is the Time imploy'd in the Ebb above Bridge; and if from the ſaid 8 Hours 30 Minutes we ſubtract 1 Hour 30', the Time of flowing from *London* Bridge to *Twickenham*, the Remains is 7, which is equal to the Time of Ebb below Bridge. Hence 'tis plain, that the Quantity of Time imploy'd for the Ebb of the Tide in theſe two Parts of the River are equal; and therefore Mr. *James*'s Aſſertion (*p.* 33.) is abſurd, where he ſays, *The ebbing Water after it has paſſed thro' the Arches of* London *Bridge meeting with no more Interruption, runs off towards the Sea with greater Velocity than the Water above the Arches can follow*; and from hence 'tis alſo evident, that tho' the Arches do obſtruct a Part of the Water at *London* Bridge, yet as there, the Velocity thro' the Arches is ſo encreaſed, that all the Water goes thro' in the ſame Time; therefo e the Water of the River from the Bridge up to *Twickenham*, &c. doth follow that below, with the ſame Velocity, and in the ſame Time as if no Bridge was there.

In the next Place, (*p.* 22.) Mr. *James* ſneers at Mr. *Hawkſmore* and Mr. *Price* together, for their having taken their Accounts of Bridges built at *Rome*, *&c.* from M. *Gautier*, and the 3d Book of *Palladio*; and points out a vaſt Difference of 192 Feet in the Extent of the *Pont Royalto* at *Venice*, between M. *Gautier* and Mr. *Hawkſmore*; but don't tell us which is miſtaken.

Nor can Mr. *James* think, that the Bridge built by *Trajan* over the *Danube*, to be a wonderful Performance, as Mr. *Hawkſmore* calls it, notwithſtanding 'tis reported to be 4600 Feet in Length, of 20 Arches, each 150 Feet Extent; and therefore ſays, *p.* 23. *I do not apprehend there was any Thing more ſtupendious in theſe, than there is in an Arch of* 100 *Feet Extent, which riſes no more than one third, or at moſt but half its Diameter. For ſup-*

poſing one of thoſe Arches to have formed a Semicircle of 75 or 80 *Feet in Height from its ſpringing; this, indeed, would have raiſed our Admiration; but for an Arch to riſe 150 Feet upon no greater Extent at the Foot than 150 or 160 Feet, is no ſuch mighty Thing, (I ſpeak* (ſays he) *as to Art, not to Expence) by Reaſon ſuch a Spand might be very well crowned with an Arch of* 80 *Feet or leſs in Diameter, if formed into a* Parabola, *or that Kind of Arch called* Catenaria, *propoſed by Mr.* Langley *for the Bridge at Palace Yard.*

If the great Length and Height of this Bridge be conſider'd, it muſt appear to have been a very great, and, I think, a very wonderful Performance; and more eſpecially as being over a deep and rapid River.

I don't underſtand what Mr. *James* means, by ſaying, There was not any Thing more ſtupendious in theſe, than in an Arch of 100 Feet Extent, which riſes no more than one third its Diameter; when 'tis allow'd that their Extent was at leaſt 150, and the Diameter of a Circle whoſe chord Line is 100 Feet, and Height 33 Feet 4 Inches, is but 108 Feet.

And tho' he ſays ſuch an Extent might have been crowned with an Arch of 80 Feet, or leſs in Diameter, as *bcn*, *Fig.* II. if formed into a *Parabola* or *Catenaria*, as *abcne*, yet he is not certain, as I can find, that thoſe Arches were not Semicircles of 75 or 80 Feet Altitude, as *bcd*, ſet upon Piers, as *ba*, *de*, which might be raiſed 75 or 80 Feet above the Surface of the River, which, he ſays, *would juſtly have raiſed our Admiration.*

It is very wonderful, that in *p.* 6. he ſeems to be afraid of medling with an Arch of 100 Feet Extent, and here he makes very ſlight of it. It is alſo to be obſerved, that granting the Arches of *Trajan's* Bridge were formed after his own Imagination, as the Curve *a h c n e*, whoſe Curvature is about 340 Feet, and whoſe Stones withſtood the Preſſure of their Weight; 'tis ſtrange, that a Curve of the ſame Kind of but 120 Feet Extent, whoſe Curvature is 160 Feet leſs, will not bear the Preſſure of its own conſtituent Parts, without ſuffering by it, as he in *p.* 8. queſtions them to do: But had Mr. *James* conſider'd, that the great Arch of *Blenheim* Bridge, which ſpands 101 Feet 6 Inches, is a Segment of a Semicircle whoſe Diameter is nearly 110 Feet; and as the Difference of Preſſure in a Semicircle of 110 and 120 Feet is not very great, he certainly would not have utter'd ſo weak an Expreſſion.

It is alſo to be obſerved, that as the Workmen of thoſe Arches made their Moulds for each Courſe, and gave them their proper Sommerings, (I believe) without infinite Trouble, *p.* 37. pray, what Reaſon can be given, that our Workmen can't perform the ſame now for Arches of much leſs Extent; and more eſpecially, as that they are not inferiour, if not much better, than any Workmen that have yet lived.

Mr. *James* next proceeds to give his Opinion, of what is offer'd by Mr. *Hawkſmore*, for building a Bridge with Legs of Stone, and Arches turned with Bricks, of which he very much approves, provided, that *the Arches in Front are turned with Stone of ſufficient Depth and Key, with Chain Courſes of Stone laid in at proper Diſtances, and Bond made in due Manner*; and as an Inſtance of the Strength and Duration of Bricks, quotes the *Pantheon* at *Rome*, as an Example. But it is to be obſerved, he by no Means is to be *underſtood, to recommend*

Rubbiſh that bears the Name of Bricks about London *to this Purpoſe*; and further adds, *'Tis Matter of Aſtoniſhment that all Houſes built with them, do not fall down, as ſome indeed have done*; and as the new Kitchen at *Greenwich* Hoſpital * would do, if the Props or Struts, placed to prevent it, were taken away; and which has deterr'd the laying on of the Floors, and render'd that Part of the Building both dangerous and uſeleſs.

I muſt beg Leave to obſerve, that as Stone Arches conſiſt of few Joints or Courſes, their Settlement will be very little (and if cloſely ſett, ſcarcely any): But Arches of Brick, having a much greater Number of Courſes, will ſettle abundantly more, by the ſhrinking or conſolidating of the Mortar; and therefore I apprehend, that to mix Chain Courſes of Stone among the Bricks, would make but indifferent Work, and the ſaving thereby very inconſiderable.

Since Mr. *James* ſays, in *p.* 47. *That Stones of* 3 *Feet in Depth in Arches of* 120 *Feet Extent, will make no Key, or have no Sommering as Workmen call it, that is, the Backs of the Arch Stones will ſo little exceed the under Sides of them, that they will have no Wedge-like Form to hang by*; how can it be expected, that Bricks of 9 Inches (whoſe Sides are parallel) will have any? Indeed, Bricks may be made of greater Thickneſs on one End than on the other, and of much larger Dimenſions than is uſual; but, I imagine, not quite ſo large as 110 Feet in Diameter, *p.* 27. as Mr. *James* ſays Mr. *Hawkſmore* mentions to be in the Arch of St. *Paul's*. (I ſuppoſe he would have ſaid, that the Arch is 110 Feet in Diameter, turned with Bricks of about 18 Inches Length, as it really is, not 110 Feet Diameter, which is abſurd.)

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* Built by Mr. *James*, &c.

That it is more eaſy, and leſs hazardous, to turn an Arch with Bricks of a ſpherical Form *as that is (of St.* Paul*'s) of* 110 *Feet Diameter; than to turn an Arch of* 50 *Feet Diameter,* 20 *in Breadth, and riſes to form a Semicircle*, is quite new to me. By ſpherical Form, a globular Form is by every Perſon of Senſe underſtood, ſuch as a Ball, &c. Good Lord! what Kinds of Bricks are theſe? Surely this muſt be an Invention wholly owing to the deep Reſearches of Mr. *James*; and 'tis fit he ſhould have the Honour of it. Had Mr. *James* been ſo fortunate, as to have invented ſpherical Bricks, when the critical Reviewer propoſed the building of an *Octangular Square*, the Novelty of their Figure, in Conjunction with that of the Square, would undoubtedly have raiſed our Admiration, and informed us, that their Inventors were Perſons of uncommon Taſte.

But, to the beſt of my Memory, there is not ſo much as one ſpherical Brick to be ſeen in any Part of St. *Paul's*, nor can they be uſed, as I apprehend, in any Kind of Building, but ſuch as are *Octangular Squares*. The only Bricks that I know to be imploy'd in St. *Paul's*, that may be conſider'd the neareſt applicable to our Purpoſe, are thoſe imploy'd in the Shell of the inward Dome, whoſe internal Surface is finely adorn'd by Sir *James Thornhill*, deceaſed; as alſo thoſe, of which the *Fruſtrum* of a Cone is made, which riſes from the Extremes of the aforeſaid Dome, thro' the Concavity of the outward Dome, for to ſupport the Lanthorn and Croſs on the Top.

Thoſe Bricks which make the former, are no other than Segments of *Fruſtrums* of various Cones, whoſe perpendicular Altitude (I mean that of the entire Cone) is equal to the *Radius* of the Dome;

and whoſe Baſe is a Portion of the external Superficies of a Sphere, equal in Diameter to that of the Dome, including the Thickneſs of its Shell.

Now as theſe Segments of *Fruſtums* have their Height equal to the Thickneſs of the Shell, and as that Height is taken from the Baſe of each Cone along its Side towards its Vertex, which is the Center of the Dome; and as the Inſide Superficies of the Dome is concentric to the outer Superficies, 'tis therefore evident, that every of thoſe Segments of *Fruſtums* muſt have ſix Faces, of which, four are curved, *viz.* two convex and two concave, as their inward and outward, and upper and lower Faces; and two that are flat and perpendicular, which have their Sommerings directed to the Center of the Dome.

Now had Mr. *James* ſaid, 'twas more eaſy and leſs hazardous to turn a Dome or Hemiſphere with ſuch *Fruſtum* Bricks, than to turn a Semi-cylindrical Arch of 50 Feet Diameter with common Bricks, he would have ſpoke like *a very knowing Perſon in the Buſineſs of Building*; becauſe every Courſe of a Hemiſphere or Dome, keys itſelf in, and diſcharges the Weight from the Center: And, indeed, every Courſe in the *Fruſtum* of a Cone, as that aforeſaid, on which the Lanthern of St. *Paul's* is placed, do key themſelves after the ſame Manner, their Sommerings being kept at right Angles to the ſlope Line of the Cone: But in all Manner of cylindrical Arches, which is what Mr. *James* means, not any Keying can be, until the very uppermoſt Courſe does that Work. This, I ſuppoſe, is what Mr. *James* calls hazardous, and leſs eaſy; but if Materials are ſound, the Centers made ſufficiently ſtrong, every Courſe have its true Sommering, and the Abutments ſecure, there's no Dif-

ficulty

ficulty or Hazard in making the largeſt Arch that can be propoſed.

As Mr. *James* has ſaid, that the Fall of Water calculated by me, to be about 12 Inches at the New Bridge, would probably have been found to be more abſurd than Mr. *Labelye*'s, had I brought it to the ſame Teſt, I will therefore bring it to that very Proof, by which it will appear how much he is unacquainted therewith.

When at the Times of Low Water, that the mean Depth at *Lambeth* Horſe-Ferry is 5 Feet ½; at the ſame Time the mean Depth of Water juſt at the Entrance of the Arches at *London* Bridge is 20 Feet. And as the ſectional Quantity of Water then freely advancing down the River at *Lambeth* Horſe-Ferry, at the Time of Low Water, has been proved to be about 3850 Feet, it is very eaſy to find what Fall that Body of Water will cauſe at *London* Bridge, where the Water Way at that Time is but 194 Feet. For if 194 be multiply'd by 20, the Product is 3880, which is but 30 Feet more than the Quantity of the River at that Time.

Now from this 'tis evident, that if the Depth of Water on the lower Side of *London* Bridge was 20 Feet at the Time of Low Water, there could not be any Fall, altho' the Piers poſſeſs more than ¾ of the River's Breadth; becauſe the ſectional Quantities of the Voids, would be equal to the ſectional Quantities of the River at *Lambeth*.

But as the mean Depth of Water on the lower Side of *London* Bridge, is then but 17 Feet, which is 3 Feet leſs than 20 Feet, the Depth then above, as aforeſaid, therefore the obſtructed Water muſt cauſe the Whole to raiſe itſelf 3 Feet on the upper Side of the Bridge, higher than on the lower, er, thereby making its Depth equal to 20 Feet as before, and cauſing a Fall equal to 3 Feet.

To make this plain to every Underſtanding, let *Fig.* III. repreſent an Arch, the Breadth of whoſe Pier *a i*, is equal to 5 Feet, and the Extent of the Arch to 25 Feet; now if the Breadth of the Pier, and Extent of the Arch be conſider'd together as the Breadth of a River, 'tis plain, that $\frac{1}{6}$ of the River's Breadth is poſſeſs'd with the Breadth of the Pier, and therefore the whole Body of Water muſt paſs thro' $\frac{5}{6}$ of the Whole, to go away in the ſame Time.

And ſuppoſing the Depth *i o* to be 5 Feet, then the obſtructed Water againſt the Pier *a i v o* will be equal to 25 Feet: Now ſeeing that this 25 Feet muſt paſs thro' the Arch in the ſame Time with the uninterrupted Water of the Arch, 'tis evident that the Whole muſt be raiſed one Foot higher, as from the Level *b y*, to *i* 13; becauſe the raiſed Parallelograms *n n v n n*, are equal to the obſtructed Parallelograms *m m m m m*, *viz.* each 5 Feet by 1 Foot, at which Time the Water againſt the Pier in the Parallelogram B, is ſtagnant.

It is on this Principle that I calculated the Fall at the New Bridge, where $\frac{1}{6}$ Part of the Water Way of the River is ſuppoſed to be obſtructed by the Piers of the Bridge, and the mean Depth of the River ſuppoſed to be ſomething leſs than 5 Feet: Now ſuppoſing that $\frac{3}{4}$ of the River's Breadth at *London* Bridge be taken up by its Piers, then $\frac{3}{4}$ of the Water will be obſtructed, provided that the mean Depth of the Water there at the Time of Low Water, is but 5 Feet; that is, if *op* be conſider'd as the whole Breadth divided into 4 equal Parts, then the Parallelogram *b g o x* may be conſider'd as the Void, and the Parallelograms *w w w* the Solid. Now 'tis evident, that the obſtructing Parallelograms *w w w* muſt raiſe themſelves on the Parallelogram *b g o x* to paſs away in the ſame Time; and as each is 5 Feet in Depth, their total Height at E will be 15 Feet, as Mr. *James* obſerves, *p.* 36., becauſe the elevated Parallelograms DDD are but equal to the obſtructed Parallelograms *www*, and conſequently they would make a Fall equal to 15 Feet. But if 'tis ſuppoſed that the Depth is 20 Feet, as *b* 3, inſtead of 5 Feet then there can be no Water obſtructed, becauſe the Parallelograms *z z*, 1 2 3 4, in this Depth, are equal to the Parallelograms *w w w* in the Depth of 5 Feet; and the Water againſt the Pier remains ſtagnant, as in the preceding Example.

Now from this 'tis evident, that if the Depth was but 19 Feet, as *g* 7, then there would be a Riſe of 1 Foot, as *k* 10; if but 18 Feet, as *g* 6, a Riſe of 2 Feet, as *k* 11; and if but 17 Feet, as *g* 5, then a Riſe of 3 Feet, as *k* 12, *&c.* And as the mean Depth on the lower Side of *London* Bridge is 17 Feet inſtead of 20, which would admit all the Water without any Fall, it therefore is raiſed 3 Feet above its natural Height, when the mean Depth of the River at *Lambeth* is 5 Feet ½; and which Fall will always be, to the Fall at the New Bridge, as the Depth of Water at *London* Bridge, whilſt between the Sterlings, is to the Depth of Water at *Lambeth* at the ſame Time.

I have in this (*mutatis mutandis*) preciſely follow'd my Manner of Calculation; and if the Reſult of Mr. *James*'s Remarks thereupon be not abſurd, I know not what is ſo.

The next Thing in Order, is his Remark on the *Catenarian* Curve, *p.* 37. which he ſays, " Al-" tho' it ſhould be granted, that Arches of this " Kind are geometrically conſider'd *the ſtrongeſt*

" of all others with Regard to their reſpective
" Diameters and Heights, yet *mechanically* * *ſpeak-*
" *ing*, perhaps, they are not ſo, on Account of
" the Difficulty of finding the proper Joints of the
" Arch Stones (which in Works of this Kind, is
" a Point of great Importance) and of unequal
" Preſſure, which may affect them in this Caſe,
" having no common Center that any two of them
" upon a Side can tend to. Add to this, that
" when *Palladio* ſpeaks of ſemicircular Arches, as
" the ſtrongeſt of all others, he gives this Rea-
" ſon for it, *Becauſe they entirely reſt upon the Pi-*
" *laſters or Piers without preſſing each other.*

I muſt beg Leave to obſerve, that whatever is geometrically true, is alſo mechanically the ſame; for it is by the Principles and Rules of Geometry that all mechanical Operations are performed; and therefore his ſaying, *p.* 37, *perhaps* they are not ſo, ſignifies, perhaps, he knows nothing of their Conſtruction and Strength, and which every one will conclude, who underſtands Geometry.

The proper Joints of the Arch Stones, I ſhall demonſtrate, when 'tis neceſſary, to be much ſtronger, than thoſe of a ſemicircular Arch, and the Molds for each Stone to be as eaſily made.

The unequal Preſſure, that he ſays may affect them, is a malicious and ignorant Aſſertion; for as every oppoſite Point in the Sides of the Curve, are at equal Diſtances from the Perpendicular, let fallen from its Vertex of the Curve unto its Diameter, the oppoſite Parts of the Curve is therefore regular, and the Preſſure of each Side equal; wherefore his Aſſertion is abſurd.

As to what *Palladio* ſays, relating to the ſemicircular Arch being the ſtrongeſt of all others, becauſe, he ſays, they entirely reſt upon the Pilaſters or Piers, without preſſing each other, is not a Demonſtration that they do ſo; the Word *becauſe* being not a Proof.

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* He means, *fooliſhly ſpeaking.*

And, indeed, if we conſider the Strength of a ſemicircular Arch, as *i* K 13, *Fig.* III. independant of Help from the Weight of its Hanches, 'tis much weaker than a Scheme Arch, as *i* L 13, where both have immoveable Abutments: For if a Weight or Force was impreſs'd on FKG, the Scheme Part of the Semicircle, ſufficient to force out its Hanches at the Points H I; the ſame Force being apply'd on MLN, which hath the ſame Extent in the Scheme Arch, could not affect that Arch, becauſe the Curves *i* M and N 13 differ very little from right Lines, and therefore are more able to reſiſt the Force than the Curves *i* F, G 13, whoſe Swellings are much greater, as the Line G 13 demonſtrates, and therefore leſs able to reſiſt: Now if this be admitted, which I believe none can deny, 'tis then very plain, that *Palladio* was miſtaken. And therefore it is to be obſerved, that unleſs ſemicircular Arches be very much loaded with Materials on and againſt their Hanches, they cannot ſuſtain any conſiderable Weight; and conſequently, if the Materials of their Spandrels are removed by Accident, or otherwiſe, the Arches will inevitably fall.

It was on theſe Conſiderations, that I have recommended the *Catenarian* Curve, which wants no Expence of Materials on its Hanches, to prevent its falling; and which cannot be broken down by any poſſible Weight that can be impreſſed on it, in Manner as on the ſemicircular Arch; of which *occular Demonſtration* ſhall be given by Models, when requir'd.

Mr. *James*'s Remark on the Strangeneſs of the *Catenaria*, not having any Part of a Circle Ellipſis, *&c.* in it, is a further Manifeſtation of his Ignorance in Geometry; for he ſays, *p.* 38, *I have always thought that there was no curved Line whatever, but was a Part of ſome Circle or other.* Strange Thinking, indeed! and if ſuch was Truth, then two Ellipſis's generated by oblique Sections of a Cone, might be ſo placed as for their Curves to be concentric to each other, which is impoſſible to be done; and therefore no Parts of their Curves can be circular; becauſe whatever is circular, may have Lines deſcribed concentric thereto.

Mr. *James* very ingeniouſly confeſſes, *p.* 38, and ſays, There is no Queſtion to be made, but Arches of this Kind are very proper, and, *perhaps, of greater Strength* than thoſe of another Form, in Places where the Extent and Height of the Arches are requir'd to be nearly equal, as in the Bridge built by *Trajan*, before mention'd. And if ſo, pray, why not the ſame in all other Extents and Heights, which he has thought proper not to meddle with.

It is very true, that the upper Part of the great Arch which extends 120 Feet, is nearly equal to a Segment of a Circle whoſe Diameter is 100 F.; and had Mr. *James* obſerv'd, that thereby ſuch an Arch requir'd no more Strength than a ſemicircular Arch of 100 Feet, his Remark had been juſt; but to ſay, that 'tis not ſo ſtrong as a ſemicircular Arch of 100 Feet, requires Explanation and Proof.

It is in this Point, that the *Catenarian* Curve exceeds the ſemicircular Arch; and therefore, the ſame Strength required for to build

A

	Feet.		Feet.	
A ſemicircular Arch of	90	Extent, will be ſufficient for the *Catenaria* of	108	Extent.
	80		96	
	70		84	
	60		72	
	50		60	
	40		48	
	30		42	
	20		36	
	10		12	

And as I have already proved, that the Weight of an Arch of 120 Feet hath not greater Preſſure on its Baſe than the Monument on *Fiſh-ſtreet Hill*, and many other publick Buildings in *England* have on theirs; what Occaſion there is to regard Mr. *James*'s Doubts and Fears, which proceeds from his real Incapacity, I cannot readily underſtand. But before I proceed further, I muſt beg Leave to obſerve, that as he allows the upper Part of the *Catenarian* Curve to approach very near to the Segment of a Circle; I hope he will allow the neceſſary Molds for the Arch Stones of thoſe Parts may be made, without infinite Trouble to Artificers, as he hath aſſerted in *p.* 37.

If Mr. *James* knew that the Angle of Incidence *b e k*, *Fig.* IV. is equal to the Angle of Reflection *f c m*, he would not have ſaid, that the Difference of the Retardation of the Velocity of the Tide between a right Angle and an acute Angle of 45° to be very inconſiderable; for as the Current againſt a right Angle will have its Courſe changed directly acroſs the River, as the direct Stream *b g* ſtriking againſt *d e* the Side of a right Angle, is directed in the Line *g i*; it will thereby retard the direct Current of the River much more than the Stream *k e*, which ſtriking againſt *b f* the Side of an acute Angle of 45°, is afterwards reflected obliquely from *e* towards *m*, which go off eaſier, and makes a much leſs Reſiſtance than *gi*. And as the leſs the Water is obſtructed in its Paſſage thro' the Bridge, the ſafer it will be for the Navigation; there is no Room to diſpute the great Advantage that the Angle of 45° hath to the right Angle of 90°.

If the Line *ef* be conſider'd to be the Outſide of the Upright of the Bridge from whence the Beak or ſaliant Angle of the Pier doth advance, 'tis plain, that the Triangle *edf*, whoſe Angle *edf* is right angled, hath a leſs Area than the Triangle *ebf*; and conſequently, the Solid raiſed on the Triangle *ebf*, is greater than the Solid raiſed on the Triangle *edf*, as I have affirmed in my Deſign publiſhed *p.* 17. Now from hence 'tis evident, that no Attempt was there made, to prove, that half of the Subſtance is more maſſive and ſtronger than the Whole, as Mr. *James* falſly aſſerts, *p.* 41; for tho' the Front Angle *ebf* contains but half the Number of Degrees that is contained in the right Angle *edf*, yet the Area of the Triangle *bef* is but to the Triangle *ebf* as 5 is to 14; and therefore a Pier built on the Triangle *bef*, whoſe Front Angle contains but 45°, will be nearly 3 Times as maſſive as a Pier built on the Triangle *edf*, whoſe Front Angle contains 90°, and conſequently of much greater Strength.

I know, that within the Limits of a right Angle, many acute Angles may be found; as the Angle *ebf* within the right Angle *abc*: But what is that to the Purpoſe? For there we not only loſe the Advantage of the acute Angle before proved, but to find the Triangle *bef*, within the right Angle, and entirely without the Upright of the Bridge, the Sides of the Piers muſt be continu'd out from *e* to *a*, and *f* to *c*; and to what Purpoſe will ſuch Continuation be?

Indeed to this it may be anſwer'd, That the Angle *edf* is a right Angle, as well as *abc*, and which is true; but then that hath its Effects on the Current as before proved; and the Subſtance of the Triangle *edf* is but $\frac{5}{14}$ of *bef*, and conſequently is much weaker. Had Mr. *James* known how to have conſider'd this Matter throughly, he might have found out his *fine-ſpun* Miſtake, *p.* 41, and not have thus expos'd himſelf as a *Zani* in the Knowledge of ſolid Geometry.

As in the working of Leavers, Pulleys, and other mechanical Powers, the greateſt Power is always apply'd at right Angles; it is therefore, that all Supports placed directly againſt the Line of Direction of all Weights they ſuſtain with right angled Bearings, are of all others the ſtrongeſt: And as in *Fig.* VI. 'tis prov'd, that the Scheme Part of the *Catenarian* Curve, as *efi*, 2 *gx*, hath its Thruſt on each Side, againſt an uninterrupted right-lin'd Solid within the Limits of the Baſe of its own Pier, as *xi* 19*r*, it therefore cannot be broken down by any Weight that can be impreſſed on the Part *efi*, whoſe Extent is equal to *yfz*.

In this Scheme I have made *fg* the Thickneſs of the Crown, equal to 4 Feet, and *ac*, *lm* the Baſes of its two Feet, upon the level of its Diameter, each equal to 8 Feet.

If on the Point *n*, with the Radius *ng* we deſcribe a Semicircle, as *cgl*, the Weakneſs thereof, with Reſpect to the *Catenaria c* 2*gxl*, is very plain by Inſpection; its Hanches, *ec* and *il*, have each a much greater Curvature, than is in 2 *c*, and *xl*, the Hanches of the *Catenaria*, and therefore liable to fly out by a ſufficient Weight laid on the Scheme *egi*; which the Hanches *c* 2, and *x l*, are not, they being, very nearly, each a right-lin'd Solid; and which being continu'd down unto *wr* the Baſe of its Pier, which is 15 Feet below *c l* the Level of Low Water, have there a ſolid Bearing, and demand but 19 Feet for the Breadth of each Pier.

The Height of the Hanches in the *Catenaria*, are thus found: 1*ſt*, Deſcribe an Arch of a Circle, that ſhall paſs thro' the outer Limits of the *Catenaria*, as *afm*. 2*dly*, Draw the Lines *dn*, *nh*, making Angles of 45 Degrees, with the Line *cl*, cutting the Semicircle *c* 3 *x* 5 *l* in the Points 3, 5; from whence, let fall Perpendiculars to the Diameter *cl*, cutting the Inſide of the *Catenaria* in the Points 2 *x*. 3*dly*, Make *xp*, and 2 *o*, each equal to *ng* the Radius of the Semicircle, and drawing the Lines *pxi*, and *o*2*e*, then *ea*, 2*c*, and *im*, *xl*, will be the Hanches requir'd; and, as *e* 2, and *xi*, are perpendicularly under *d* 3, and 5 *h*, the Extreams of the Hanches to the Semicircle, they do therefore ſuſtain a Scheme of the ſame Extent and Height, as that of the Semicircle, but with an Abundance more Strength as before prov'd.

If from the Points 5 *h*, we draw right Lines, as *ht*, 5 *s*, at right Angles to the Line *hn*, they will cut thro' the Outſide of the Pier at *st*, 21 Feet above Ground. Now ſeeing that the Thruſt of the half Scheme *fhx* 5, is againſt 5 *hts*, 'tis plain that if the Part *zvis* be remov'd by Accident, or muſt be remov'd on ſome certain Occaſion, the whole Scheme Part *dfh*, will inevitably fall, as having nothing to reſiſt its Force or Thruſt.

If Mr. *James* will but conſider this Particular throughly, he will be no longer an Advocate, for the Strength of the ſemicircular Arch, altho' *Pal-*

ladio has miſtakenly recommended it. And if the Right Honourable the Commiſſioners are pleas'd to direct their Commands to me, I will prove all that I have here ſaid, by Models of both Kinds of Arches, made for that Purpoſe, wherein the *ſuperiour Strength* of the *Catenarian Curve*, will not only be demonſtrated, but the *proper Joints* of its Stones alſo.

I am not unacquainted with the Effects of Weight on the Hanches of Arches, and well know that the *Want of Extent* for the Abutments or Piers of Arches, ſuch Weight will do the ſame Office; but, as I before obſerved, if ſuch Weight muſt be removed on any Occaſion, or happens to be ſo, by unforeſeen Violence, then nothing can prevent this diſmal Conſequence, the innevitable Neceſſity of their falling. Beſides, as the Expence of ſuch Weight will be very conſiderable in a Work of this Magnitude; and as the Buſineſs can be effectually done without it, why muſt ſuch Inconveniencies, Dangers, and Expences be run into, when ſo eaſily avoided?

As to what Mr. *James* ſays with Reſpect to Time, *p.* 43, or Violence breaking down Arches, I never made any mention thereof; for as the hungry Teeth of Time deſtroys all Things, ſo thereby the moſt durable Stone will be reduced to Atoms; and the violent Aſſaults of Cannon may batter it to Pieces.

I believe every judicious Perſon will allow, that in a Work of this Magnitude, the leſs the Foundation is loaded with extraordinary Weight, the leſs liable the Whole will be to unequal Settlements; and as both the Weight and Expence will be greatly abated by the horizontal Cylinders that I have recommended; for what Reaſon muſt they be rejected? and more eſpecially as that their Vacuities being made ſolid, will not be any additional Strength (but rather an Injury) to the Whole.

Indeed to make theſe Vacuities in the Spandrels of ſemicircular Arches, would be doing a Miſchief, as Mr. *James* obſerves, *p.* 43, becauſe as their great Thruſt is above the Baſe Line of their Piers, they have no other Security but the Weight of their Spandrels to prevent their falling; and as thoſe Spandrels on each Side the Bridge, will be unequal in every Arch, which is occaſion'd by the Declivity of the Bridge, therefore every of them will be unequally preſſed, and that very greatly, which, as Mr. *James* obſerves, *p.* 37, may affect them. Add to this, that by ſuch unequal Preſſure on each Side, every Arch becomes dependant on one another, and the Whole on the Abutments on each Shore; and therefore 'tis evident, that if thoſe Abutments give Way, or are removed by any Means, the whole Bridge will undeniably be endanger'd, as I have already obſerved, *p.* 20, in my firſt Deſign for this Bridge.

Mr. *James*'s next Sneer is at the Independancy of the *Catenarian Arches*, the Truth of which has been already proved in *Fig.* VI. and ſhall be yet further proved when required, as likewiſe, that the making of Abutments on the Shores is unneceſſary; and that 'tis no Matter which of the Arches is firſt built; and that any one of them may at any Time be taken down and rebuilt, without any Danger to the next adjoining, as I have aſſerted in *p.* 22 of my firſt Deſign for this Bridge, and which I apprehend cannot be done if the Arches are made ſemicircular, as Mr. *James* recommends.

I am not in the leaſt concern'd, at Mr. *James* being perſuaded *p.* 44, *no one would venture upon my Judgment to attempt the building of a Series of Arches independant of one another, without the Aſſiſtance of proper Abutments, upon each Shore:* By proper Abutments on each Shore, I underſtand to be ſuch, whoſe Strength is capable to reſiſt any Force that may be apply'd againſt them. Now 'tis plain, that if by the Conſtruction of the Arches, they are made actually independant, of each other; and every Arch ſuſtain its own Weight, on the Baſe of its Piers, then there cannot be any Thruſt againſt the Shores; and conſequently, the making of Abutments, where none are requir'd, will be a very great and unneceſſary Expence. It may be, *p.* 44, that Mr. *James may find out Methods to make Arches of a better Shape, and Piers with ſuch Proportion, as would render them as firm in themſelves, and as independant of one another, as thoſe propos'd by me:* If he is Maſter of ſo much Geometry, (which I much queſtion, and which is very evident he is not by what hath been already proved) as is ſufficient for ſuch a Performance. I am certain, he will find it a much greater Task than he imagines: And as Improvements of Arts, are Advantages to the Publick; I ſhould be well pleas'd, to ſee from Mr. *James* the Demonſtration of another Kind of Curve, that is ſtronger than the *Catenaria*, or even of equal Strength and Independancy; which I hereby challenge him to perform, and make publick, and which will be the only Proof, that he's not an Impoſtor.

The Blunder he's pleas'd to charge me with, *p.* 45, of 24,174 *l.* being placed in the Stead of 159,254 *l.* was an Error of the Preſs, not my own, and which he confeſſes to be ſo, becauſe, ſays he, *p.* 45, in the following Page he acknow- the ſame to be 159,254 *l.* at 1 *s.* 6 *d.* *per* Foot cubical.

In *p.* 46, Mr. *James* takes upon him to diſprove the Truth of the Quantity of Brick-Work that may be ſaved by the cylindrical Vacuities I have recommended, which in *p.* 24 of my *firſt Deſign, publiſh'd for this Bridge*, I have ſaid to be 322,322, cubical Feet, equal to 1020 Rods; and which Mr. *James* falſly ſays, *p* 46, *the Number of cubical Feet, above-mention'd, are equal to* 1185 *Rods of Work, at* 272 *Feet to the Rod, and conſequently amount to* 11850 *l. at his* (meaning my own) *Reckoning*, which is 1650 *l.* more than 10,200 *l.* the Amount according to my Calculation.

'Tis well known to every Bricklayer, that 272 Feet $\frac{1}{4}$, at 1 Foot 2 Inches the Standard Thickneſs, of Brick-Work is call'd a Rod of Work.

Now if 272 Feet 6 Inches be multiply'd by 1 Foot 2 Inches, the Product is 317 Feet $\frac{11}{12}$; and rejecting the Fraction $\frac{11}{12}$, if 322,322, be divided by 317, the Quotient is 1016, the Exact Number of Rods in the Whole. In *p* 24, of my firſt Deſign publiſh'd for this Bridge, I rejected the odd Foot and $\frac{11}{12}$, and divided 322,332, by 316, whoſe Quotient is 1020, which makes but 4 Rods more than the real Quantity aforeſaid, tho' meaſur'd with the utmoſt Strictneſs that is practic'd in Trade.

If this be conſider'd, 'tis plain, that Mr. *James*, *p.* 6, is actually one of thoſe who are not Maſters of ſo much Geometry as to come at the Meaſures of the Number of cubical Feet in one Rod of Brick-Work; for tho' 272 ſuperficial Feet are allow'd to make one Rod of Brick Work, yet their Thickneſs muſt be conſider'd at 1 Brick and $\frac{1}{2}$, the Standard Thickneſs, equal to 1 Foot 2 Inches, and not at 1 Foot only, as Mr. *James* has abſurdly done in his Calculation of 1185 Rods, which wants but 8 Feet $\frac{1}{2}$ in every Rod of being $\frac{1}{3}$ Part of the Whole, more than it really is. If the Works conducted by Mr. *James* have been thus meaſur'd, Woe then to their Proprietors! the Workmen may very well make rich Preſents of Silver Tea-Kettles, Lamps, *&c.* of very great Value, as I have heard, many have done.

The Manner of making the Coffer-Dams which I have recommended to be us'd, where the Bottom is a Strong Clay, doth certainly require ſomething more than Words to explain the Manner of making, and removing them from one Pier to the other; and for which Purpoſe, I will make a Model, if requir'd, by which that Operation may beſt be underſtood; and wherein Mr. *James* may ſee, what I mean by Caſes filled with ſtiff Clays.

If in the Foundation the Limits of the Baſe of every Pier, be bounded with Piles Dove-tail'd together, there's no Doubt but that the greater the Number of Piles driven within them are, the more compact that enclos'd Foundation will be, and conſequently will be the better able, to ſuſtain the Weight of the Superſtructure: It is therefore that I adviſe, the driving of Piles within the Limits of each Pier, as cloſe together as can poſſibly be done. Obſerving at the ſame Time to make the Whole thereby as nearly equally compact as can be, which to perform, and the Manner of driving the Piles, in the moſt Expeditious Manner, I reſerve to another Opportunity.

I am not inſenſible of the Weight and Quantity of Water that muſt be remov'd to ſink a concave Parallelopipedon ſtrongly fram'd together, of the beſt Oak, which Mr. *James* calls a hollow *Cheſt* or *Coffer*, of Dimenſions within, equal to the greateſt Pier; which to ſink 6 Feet below the Bed of the River, at the Time of High Water on a common Spring Tide, when the whole Depth will be about 22 Feet, will require its being filled with *Portland* Stone unto 12 Feet in Height from its Bottom; whoſe Weight, excluſive of the Framing, *&c.* is 4527 Tuns, which is 527 Tuns more than Mr. *James* makes it to be, *p.* 51. And altho' Mr. *James* ſays, *p.* 50, that the Foundations of the Piers cannot be laid in ſuch Coffers, without breaking their Backs, and diſlocating the Bond of the Work; yet I am ſo much convinced of his Miſtake, that I will ſubmit to be executed as a Felon, if I miſcarry'd in laying the Foundation of any one Pier in that Manner. But, however, as the Trial thereof may amount to a greater Expence, than perhaps may be agreeable to be riſqued on my Life, whoſe Value is very inconſiderable; the ſame Work may be very eaſily and as effectually perform'd, by dividing the Length of each of the great Piers into 14 equal Parts; and ſinking each Part ſeparately, in a ſmall Coffer of its own Dimenſions, as repreſented in *Fig.* V.

And as the Altitude of ſuch Foundation, *viz.* 12 Feet from the Bottom, will then be 1 Foot above the Height of Low Water; if the Sides *a a*, *&c.* be taken away, and their Meetings *b b*, *&c.* be made cloſe and entire, then ſmall Arches being turned over *a a*, *&c.* the whole Length of each Pier may be firmly bonded together, and worked up entirely ſolid, unto any Height required.

I will not undertake to ſay, what other Methods may be propoſed, for the Performance of this Work, in ſuch Parts where the Water within the Bed of the River cannot be kept out, whilſt the Foundations are laying and bringing up; but glad ſhall I be, to ſee a better Method made uſe of than this I have propoſed.

As 'tis not in Mr. *James*'s Nature to allow that any Perſon beſide himſelf, know, or have done any Thing New; 'tis no Wonder, that he has the Aſſurance to ſay, That the Sketch, *Fig.* IV. in my firſt Deſign, publiſh'd for this Bridge, is taken from a good Author; was ſuch the Truth, he would have as certainly diſcover'd that Author's Name, as he has that of M. *Gautier*'s, with Reſpect to Mr. *Price* and Mr. *Hawkſmore*.

Mr. *James* having gone thro' the Obſervations he propos'd, and given ſome Hints and Computations of Uſe, as he is pleas'd to call them, for the Quantity and Weight of Stone preſſing on the Foundation of an Arch; which, by the preceding, is very manifeſt, and which will yet be further prov'd; 'tis really, very ſurprizing, that he dare venture to undertake an Arch of 80 Feet, or even of any greater Extent, than one of the Kitchen Windows in *Greenwich* Hoſpital.

Mr. *James* proceeds, p. 54, and ſays, *It is certain, that two Arches of* 60 *Feet each, as Fig.* VIII. *gain* 20 *Feet more, than one of a* 100 *Feet in Extent, as Fig.* IX. *That a Pier of* 10 *Feet in Thickneſs as* d e k l *will ſuſtain the former better, than a Pier of* 20 *Feet will the latter; and that the Arches, over the two former, upon the ſame Proportion of Depth, will not take up ſo much Stone to cover them, as the former, by* 1500 *Tuns.*

It is as certain, that two Arches, each of 60 Feet, contain 20 Feet more Water-Way than one Arch of 100, as that they have a poor, beggarly, and dangerous Aſpect, whilſt that of 100 Feet, *Fig.* IX. appears *Grand* and *Magnificent*, and the Paſſage under it open and free: But that a Pier of 10 Feet in Thickneſs, as *d e k l*, will ſuſtain thoſe Pidgeon-Hole Arches, better than a Pier of 20 Feet, as *lkmp*, will the latter, I muſt own, is quite new to me; for if the Foundations to every Arch be firm and ſecure, and as I have prov'd that the Weight of Stone in an Arch of 100 Feet Diameter is much leſs, than many publick Buildings, and as our Stone is as good now, as heretofore; Pray, How is the word *Better* to be underſtood? Beſides, I believe it will puzzle Mr. *James*, and all his Emiſſaries, to prove, That the Weight of an Arch of 100 Feet Extent, as *Fig.* IX. whoſe Thickneſs *li* is equal to 8 Feet, and loaded with Spandrels level with its Crown, is ſuſtain'd by any other Parts of its Piers, more than 1 *cig*, and *limn*, which are each equal in Extent to 8 Feet, the Thickneſs of the Arch. If this be maturely conſider'd, it will appear very evident, that *iknp* the remaining Thickneſs of the 20 Feet Pier, is of no other Uſe, than to ſuſtain its upper Part *obik*; and therefore 'tis plain, that even, a Pier of 10 Feet in Thickneſs, which Mr. *James* thinks to be neceſſary for the Support of two Arches each of 60 Feet, is 2 Feet more than is requir'd to ſupport one $\frac{1}{2}$ of an Arch of 100 Feet, with that unreaſonable Thickneſs in its Crown of 8 Feet. The Arch over *Traytors Gate* at the Tower of *London* is a Segment of a Semicircle whoſe Diameter is 78 Feet, and its Vouſſoirs but 2 Feet 7 Inches in Height. And thoſe Arches of 60 Feet Extent, and 4 Feet in Thickneſs on their Crowns, being thus conſider'd, require but 4 Feet Extent on each Side for their Baſe; not 5 Feet, as Mr. *James* has aſſign'd them, which in each is 1 Foot Extent too much.

But before I proceed to calculate the Quantity of Stone requir'd to form theſe ſeveral Arches, and further to explain Mr. *James*'s Ignorance in the Menſuration of ſuch Works, I muſt beg Leave for a ſhort Digreſſion, to prove, that there's no Neceſſity of making the Crown of an Arch, of 100, or 120 Feet in Extent, more than 4 Feet in Thickneſs. In *Fig.* VII. is repreſented, three Arches of Stone, as ABC, each of 4 Feet in Thickneſs, making together a Thickneſs equal to 12 Feet.

Now if 'tis granted that every Arch, after its Center is removed away, has ſome Settlement, as in Fact they all have (more or leſs, according to the Number of Joints and Quantity of Mortar in each) 'tis evident, that the Stones have not their true Bearing until the Center is ſo ſtruck, and therefore the Building of one or two Arches over the firſt, as the Arches AB on the Arch C, is no Addition of Strength to the Whole; for as the Stones in the Arch C, will not give Way, for the Stones in the Arches AB, to ſettle, as aforeſaid, to take their true Bearings, they therefore cannot help to ſuſtain any Weight that may be laid on them, and are therefore an Injury or unneceſſary Weight on the Arch C, inſtead of being a Strengthening to the Whole.

And if we ſuppoſe that they are all turn'd at the ſame Time, before the Center be ſtruck, and take their Settlements together, 'tis plain, that the under Arch which has the feweſt Number of Joints, will ſettle the leaſt, and thereby prevent the neceſſary Settlements of the other two from following it, and conſequently, they will ſtill be no other than an unneceſſary Load as aforeſaid.

But if contrary to theſe Proofs, it be allow'd, that every Arch, hath its juſt Bearing independant of each other, 'tis then evident, that whatever Weight be laid on the upper Arch, cannot have any Effect on the Arch B, and conſequently not on the Arch C neither; and if ſo, of what Uſe are the Arches BC. Now from this, 'tis evident, that until the Strength of the Arch A be deſtroy'd, the Arch B, cannot act, to ſupport any Weight but its own; and therefore as the Arch A and B are equal in Thickneſs, that Weight or Power, that can deſtroy firſt the Arch A, can afterwards deſtroy the Arch B, and after that the Arch C likewiſe. Whence it follows, that any one of the three Arches, will ſuſtain the ſame Weight, as all of them taken together,

If Mr. *James* had conſider'd this, he would not have aſſign'd 8 Feet for the Thickneſs of an Arch of 100 Feet Extent.

And, indeed, if 'tis conſider'd, that the Key Stone of an Arch, ſuſtain the very leaſt Part of the whole Weight; and that the Stones on each Side, become immediately, of greater Dimenſions in Height, 'tis very plain, there's no Neceſſity of making them ſo monſtrouſly high, which alſo occaſions, an extraordinary Weight of Stone on each Side, to riſe up level with their Heads more than need to be.

I humbly conceive, if a ſemicircular Arch, as *Fig.* IX. be made 4 Feet in the Crown, as *eg*, and 7 or 8 Feet in its Springings, as at 1 *c*, and *li*, and its Spandrels work'd up level with the Crown; that it will be equally as ſtrong as if made of 8 Feet Thickneſs in the Crown, as Mr. *James* recommends, which, if I am not miſtaken, will occaſion not only an unneceſſary Expence, but will be loading the Foundation with an unneceſſary Weight alſo.

Thus much by Way of Digreſſion: I ſhall now proceed to ſhew the abſurd Calculation of Mr.

James, made, to find the Quantity of Stone neceſſary to cover the aforeſaid Arches.

In *p.* 54, ſays Mr. *James*, the Periphery of a ſemicircular Arch of 60 Feet in Diameter, as F, taken upon the under Side of the Arch Stone *cgd*, *Fig.* VIII. is about 94 Feet; that of the 100 Feet Arch, *Fig.* IX. as G, about 157: Now ſuppoſing the Depth or Thickneſs of the Arch Stone to be 4 Feet in the former, and to be 8 Feet in the latter, and the Breadth of the Bridge to be 50 Feet from out to out of the Walls: Then, ſays he, will 94 Feet multiply'd by 50, and that Product by 4, produce 18,800 cubical Feet; and 157, the Periphery of the 100 Feet Arch, multiply'd by 50, and that Product by 8, will produce 62,800 cubical Feet; which two Products he imagines to be the ſolid Contents of the two Arches.

Now had Mr. *James* the Senſe but to have ſubtracted 1414 $\frac{2}{7}$, the Area of the Semicircle *cgd*, from 1816, the Area of the Semicircle *zxy*, and multiply'd 402, the Remains, by 50 the Breadth of the Bridge, he would have found 20,100 for the Product, which is the exact Number of cubical Feet in one Arch of 60 Feet, at 4 Feet Depth of Stone; being 1300 cubical Feet more than the Quantity he aſſerts, *p.* 54, and which doubled for the two Arches of 60 Feet each, is a Blunder of 2600 cubical Feet, equal to 162 Tons $\frac{1}{2}$.

In the ſame Manner, the Area of the Semicircle *cgl*, 100 Feet Diameter, equal to 3928 Feet $\frac{1}{2}$, being ſubtracted from 5286 $\frac{2}{7}$, the Area of the Semicircle 1 2 *i*, 116 Feet Diameter, the Remains is 1357 $\frac{11}{14}$, which multiply'd by 50, the Breadth of the Bridge, the Product is 67,850, which is the true Solidity of that Arch, at 8 Feet Depth of Stone, and which is another Blunder of 5050 cubical Feet, equal to 315 Tuns 10 Feet, making together but 478 Tuns 2 Feet; a Quantity, it ſeems, too inconſiderable for Mr. *James* to regard.

If 20,100, the Solidity of 1 Arch of 60 Feet Extent, be doubled, 'tis equal to 40,200, the Solidity of both thoſe Arches, and which being taken from 67,850, the Solidity of the 100 Feet Arch, the Remains is 27,650, which is 2450 cubical Feet more than ſaid to be by Mr. *James*; and therefore the real Difference of Stone in theſe propoſed Arches, is actually 1728 Tuns $\frac{1}{2}$, and not 1575 Tuns, as Mr. *James* aſſerts them to be, *p.* 55, and which is 153 Tuns $\frac{1}{2}$ leſs than the Truth.

As I have thus demonſtrated the abſurd Calculation of Mr. *James*, and have prov'd that there's no Neceſſity of making the Crown of an Arch of 100 Feet Extent, more than 4 Feet; and that the Extent of its Baſe on each Side, need be no more than 8 Feet; I will therefore in the next Place ſhew, how much Stone is requir'd to build an Arch of 100 Feet Extent, more than for 2 of 60 Feet each.

If from 6300, the Area of the Parallelogram *abbm*, *Fig.* VIII. be ſubtracted 4148, the Area of the two Vacuities F and G taken down to the Line *im*, the Remains 2152, is the Area of the Face to the Spandrels and Piers, and which being multiply'd into 50, the Breadth of the Bridge, produces cubical Feet 107,600, equal to 6725 Tuns.

And if from 7410, the Area of the Parallelogram *boin*, *Fig.* IX. be ſubtracted the Area of the Void *gc* G *lm* 5028, the Remains 2382 is the Area of the Face of the Spandrels, and which being multiply'd into 50, the Breadth of the Bridge, produces cubical Feet 119,100, equal to 7443 Tuns 12 F. which is but 718 Tuns 12 Feet more than in the preceding.

Now if from 1575 Tuns, the extraordinary Quantity ſaid to be by Mr. *James*, *p.* 55, be ſubtracted 718 Tuns 12 Feet, the real Difference, the Remains 856 Tuns is the actual Quantity of Stone that would be imploy'd by Mr. *James*, more than need be; which at 3 *s. per* Foot, for Stone, working, and ſetting, amounts *but* to 2054 *l.* 8 *s.*!

Mr. *James* tells us, *p.* 57, *That the Calculations he has hitherto made, do not only concern the cubical Quantities of Stone requiſite for the Work, but the Workmanſhip itſelf, and the Charge of raiſing and ſetting it alſo.*

I muſt here obſerve, that if thoſe Calculations are made by ſuch Methods as the Calculations he has publiſh'd, they are not to be depended on, as being very falſe; his Brick being much too much, and the Stone-Work much too little: And tho' both have been here fully proved, by many Examples, yet I ſhall beg Leave to add the Abſurdity of his next and laſt Calculation, as following, *p.* 57.

For, ſays he, *the Work of the Face of the Arch Stones, in an Arch of* 50 *Feet Extent, amounts to no more than* 78 *Feet* 6, *by* 3 *Feet* 4 *Inches, which produces* 261 *Feet* 8 *Inches ſuperficial; whereas in an Arch of* 100 *Feet wide, the Face is* 157 *by* 8, *which makes* 1256 *Feet ſuperficial.*

Now the Abſurdity hereof is very plain; for if from 1285, the Area of the Semicircle $a \times 1$, be ſubtracted 982 $\frac{1}{7}$, the Area of the Semicircle $d z n$, the Remains 302 $\frac{6}{7}$ is the Area or ſuperficial Feet contained in the Face of the Arch $a d x z n 1$, which Mr. *James* makes to be but 261 Feet 8 Inches, and which is 41 Feet $\frac{3}{14}$ leſs than the Truth.

Now to explain the Quantities of Materials requir'd in ſmall and large Arches, ſtanding over Rivers of equal Breadth; let GH, *Fig.* XI. repreſent two Arches, each 50 Feet, ſuſtain'd at I by a Pier of 8 Feet 4 Inches in Breadth, which is equal to $\frac{1}{6}$ of their Apertures; and let *a d*, *c b*, the Breadth of the Face of each Arch, be equal to 3 Feet 4 Inches, making together 115 Feet.

Alſo let the Arch F, *Fig.* X. extend 107, and *ef*, *gb*, the Breadth of the Face of the Arch on each Side, each 4 Feet, which together make 115 Feet, equal to *ab*.

If from the Sum of the Area of the Parallelogram *ikab*, and Area of the Pier *nmob*, be ſubtracted the Area of the two Semicircles G and H, the Remains is equal to 1285, the Area of the Spandrels, *ik*, *&c.* and if from the Area of the Parallelogram *c d e b*, we ſubtract the Area of the Semicircle F, the Remains is 2615, the Area of the Spandrels *cd*, *&c.* And if from 2615 Feet, the Area or ſuperficial Content of the Spandrels *e c d b f x g*, we ſubtract 1285, the Area of the Spandrels *d a i k b c*, *&c.* the Remains 1330, is the Quantity of ſuperficial Feet that are more in the Face, *&c.* of the Arch of 107 Feet Diameter, than is in the two Arches of 50 each; which is but 35 Feet more than 2570 the double Area of *d a i b b c*, and admits of 7 Feet more Water-Way.

If from 2206, the Area of the Face of the Spandrels and Arch, *Fig.* IX. exclusive of the Area of the Face, of its Piers 1 *c i g*, and *l i m n*, we ſubtract 1285, the Area of the Spandrels, *&c.* to the two 50 Feet Arches, *Fig.* XI. the Remains is 921, which is 42 Feet, leſs than $\frac{3}{4}$ of 1285. And as I have prov'd, that a Thickneſs of four Feet on the Crown of an Arch, is ſufficiently ſtrong, 'tis plain that Mr. *James*'s Manner of comparing the Arch of 50 Feet with that of 100 Feet Extent (which he ſays is little leſs than five Times the former) is ſuprizingly abſurd; he might as well have increas'd the Thickneſs of the Crown and Altitude of the Whole, ſo as to have made it 20 Times the former; when in real Truth, being made of ſufficient Dimenſions, as aforeſaid, the Area of the Arch of 100 Feet is not quite once and ¾ of the Area, of the Face to the two 50 Feet Arches with their Pier, as is evident by the preceding.

I ſhould be glad to ſee from Mr. *James*, or any other Perſon, a Geometrical Demonſtration, to prove, that 3 Feet is not ſufficient for the Thickneſs of the Crown of an Arch, made of good *Portland* Stone, of 120 Feet Extent; and which I challenge, both him, and the celebrated Wits of the preſent Board of Works, to produce *.

Mr. *James* being weary'd out in his further Review, he now humbly propoſes, that for the future, Watermens Boys be oblig'd to play at 15 Holes, inſtead of 9 Holes, *the middle Hole to be* 80 *Feet in Extent, and the reſt gradually decreaſing by* 6 *Feet* 8 *Inches each, to the leaſt Hole of* 33 *Feet* 4 *Inches*; Theſe with proportionable Solids between the Holes, muſt needs raiſe their Admirations: And, Indeed, I very much queſtion, if it will not be judged a very neceſſary Pattern for making a new Kind of *Miſſiſſippi* Tables; and for the better proportioning the Apertures to Pidgeon-Houſes, according to the different Sizes and Kinds of Pidgeons, which is a Part of Architecture hitherto unthought on: It being common to make every Hole of the ſame Size, without any Regard to the different Magnitudes, and Dignity of the Inhabitants.

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* *Vide* the Poſtſcript.

If Mr. *James*, had but read the *Nota Bene* to my Poſtſcript, *p.* 30, he would have ſeen 'twas propos'd, to abate the Altitude of the two outermoſt Arches on each Side, for to make an eaſy Aſcent for Waggons, *&c.* in Caſe a ſufficient Baſe on the Shores of each Side, could not be obtain'd for that Purpoſe.

Much more than I have Room for, *p.* 58. (or Time,) *at preſent*, *might be ſaid upon* the *Abſurdities* of Mr. *James*'s Calculations, which ought to be tranſmitted by Record to Poſterity, there being ſcarcely any of them, that *being very well ſcann'd and conſider'd*, but are the moſt ſhameful of any that I ever heard of, or ſee made publick; and therefore cannot *be thought of any Weight*, by the Right Honourable and Honourable Commiſſioners, which he ſeems to flatter himſelf with the Hopes of. And, as he further adds, *p.* 59. That *he ſhall at any Time be ready farther to explain or ſupport*, *what has been deliver'd by him*; Let him therefore, if in his Power, be as good as his Word, without Loſs of Time.

Parliament-Stairs,
Jan. 27th 173$\frac{6}{7}$.

Batty Langley.

POSTSCRIPT.

THo' Mr. *James* has been pleas'd to ſneer at Mr. *Hawkſmore* and Mr. *Price* for their having tranſcrib'd from *Gautier* their Accounts of Foreign Bridges; yet he has forgot to tell us, that the Thickneſs of 3 Feet 4 Inches which he has aſſign'd for the Crown of an Arch of 50 Feet in Diameter, and of 6 Feet 8 Inches for the Thickneſs of an Arch of 100 Feet in Diameter, are alſo taken from *Gautier*'s Table of the Lengths of Vouſſoirs, in his Diſſertation *ſur les Culeres, Vouſſoirs et Piles de Ponts, p.* 368.

And although this Table, is calculated from the Works of the Ancients, who for Want of Geometrical Demonſtrations, did generally overload theſe Kinds of Buildings, as is evident by *London* Bridge, and many other ſuch maſive Bridges; yet M. *Gautier* doth not ſo much as ſay he can demonſtrate the Neceſſity of thoſe Dimenſions, or that any Perſon did ever attempt ſo to do. And, indeed, if we conſider, that the Crown of an Arch, doth ſuſtain no more than the Weight of that Part of the Pavement, *&c.* that is directly over it, which is the leaſt Part of the Whole; 'tis evident, that no ſuch prodigious Strength as that Table doth expreſs, is requir'd; and which would not only encreaſe the Weight very greatly on the Foundations of the Piers, but cauſe a very great Addition to the Expence alſo, and therefore is abſurd.

And for a further Proof of this Abſurdity, let it be conſider'd, that the great Arch over *Traytors Gate* at the Tower of *London*, (which is a Segment of a Semicircle of 78 Feet in Diameter), hath but 2 Feet and 7 Inches for the Length of the Vouſſoir in its Crown, as I have before noted; and which hath ſuſtained for many Years, a much greater Weight than the Crown of any Arch in this intended Bridge, will be requir'd to do.

N. B. The Thickneſs aſſigned for the Crown of ſuch an Arch, by M. *Gautier*'s Table, from which Mr. *James* ſeems to make his Calculations, is 5 Feet 2 Inches $\frac{1}{2}$, which is $\frac{1}{2}$ an Inch more than double the Thickneſs of that at *Traytors Gate*.

FINIS.